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Aquatic Plant Control Research Program

Evaluation of Eurasian Watermilfoil Control Techniques Using Aquatic Herbicides in Fort Peck Lake, Montana

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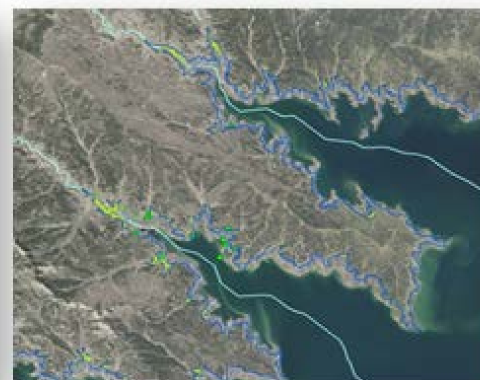

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Final report

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Abstract

In 2012, field trials were conducted in Fort Peck Lake to evaluate herbicides for controlling Eurasian watermilfoil and to provide management guidance. Plots of 1 to 3 hectares were treated with the herbicides (Dredge Cut, endothall at 2000 micrograms per liter (µg/L); Rock Creek South, endothall at 2500 µg /L, triclopyr at 2000 µg /L; Rock Creek North, endothall at 2000 µg/L, triclopyr at 2000 µg/L; Reference, no herbicides) using a variable-depth application technique. The Dredge Cut was an open-water site protected with a barrier curtain to sequester water exchange, where endothall was maintained ~ 1500 µg/L for 24 hours after treatment (HAT), providing 96% control of milfoil by 4 WAT but only 22% control at 50 WAT. Rock Creek South was an open-water plot where water exchange processes diluted herbicide levels (endothall < 300 µg /L and triclopyr < 500 µg /L by 6 HAT), and milfoil control was limited to 7% at 4 WAT and 99% control at 50 WAT. Limited water exchange processes in Rock Creek North resulted in slow dissipation of herbicides (endothall ~ 700 µg /L and triclopyr ~ 800 µg /L for 24 HAT), and milfoil control was 100% at 4 and 50 WAT. Periods of low water levels in the lake impacted the 50 WAT efficacy results in plots above the dam. Native vegetation was sparse in all plots but survived treatments with an increase in species diversity at 50 WAT. Treatments had no impacts on water quality including dissolved oxygen levels. Adequate control of milfoil can be achieved in areas of the lake where water exchange processes are reduced and herbicide concentrations surrounding target plant stands can be maintained.

Contents

Figures and Tables

Figures

Tables

Preface

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APRCP). The APCRP is sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Research and Development Center (ERDC) under the purview of the Environmental Laboratory (EL), Vicksburg, MS. Funding was provided under 96X3122 and by the U.S. Army Engineer District, Omaha. The APCRP is managed under the Civil Works Environmental Engineering and Sciences Office, Dr. Alfred Cofrancesco, EL, Technical Director. Dr. Linda Nelson, EL, was Assistant Technical Director and Program Manager for the APCRP.

This work further involved the cooperative effort of the Fort Peck Project Office, U.S. Army Engineer District, Omaha; Tetra Tech, Inc. (Portland, OR); and the Aquatic Ecosystem Restoration Foundation (Flint, MI). Work was coordinated with the Charles M. Russell National Wildlife Refuge, a major stakeholder on Fort Peck Lake.

The Principal Investigator of this work was Dr. Kurt D. Getsinger, Environmental Processes Branch (EPB), Environmental Processes and Engineering Division (EPED), EL. This work was conducted and the report prepared by Dr. Toni Pennington, Tetra Tech, Inc. (Portland, OR); Dr. Getsinger and John Skogerboe, EPB; and Patricia Gilbert, U.S. Army Engineer District, Omaha.

The authors acknowledge the contributions of Marci Netherland, University of Florida Center for Aquatic and Invasive Plants, for herbicide residue analyses and field assistance of Tim McNew, Larry Vetch, Tom Weber, and John Kulczyk of the Fort Peck Project Office. Herbicides were provided by United Phosphorus International (King of Prussia, PA), and herbicide applications were conducted by Clean Lakes, Inc. (Coeur d'Alene, ID).

Appreciation is also extended to personnel from the following agencies that visited the treatment sites during the applications and post-treatment monitoring:

- Valley County Weed Control–Rick Stellflug

- Montana Department of Agriculture, Pesticide Enforcement Division–Diana DeYoung
- Montana Department of Agriculture, State Weed Coordinator–Dave Burch
- Montana Department of Agriculture, Aquatic Plant Science Specialist–Craig McClain
- Montana Fish Wildlife and Parks–Bill Viste
- U.S. Army Engineer District, Omaha, Invasive Species Coordinator–Jonas Grundman.

Technical reviews of this report were provided by Dr. Christopher Mudge, EPB, and Dr. Harry Gibbons, Tetra Tech, Inc.

This work was performed under the general supervision of Dr. Beth Fleming, Director, EL; Warren P. Lorenz, Chief, EPED; and Mark Farr, Chief, EPB. At the time of publication of this report, Dr. Jeffery P. Holland was Director of ERDC. LTC John T. Tucker III was the Acting ERDC Commander.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
hectares	1.0 E+04	square meters
Inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
mils	0.0254	millimeters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pints (U.S. liquid)	4.73176 E-04	cubic meters
pints (U.S. liquid)	0.473176	liters
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

1 Introduction

The invasive Eurasian watermilfoil (*Myriophyllum spicatum* L.) is a widespread nuisance plant in lakes, rivers, ponds, and reservoirs in the United States. Its distribution throughout Montana, while comparatively less than most states, has spread rapidly since first reported in Noxon Rapids and Cabinet Gorge Reservoirs in the Columbia River drainage in 2007. It is known to occur in Broadwater, Flathead, Gallatin, Jefferson, Lake, Sanders, Garfield, McCone, Phillips, and Valley counties, which includes the Missouri River drainage. Eurasian watermilfoil was first observed in Fort Peck Lake in 2010, and it is now known to occur in over 100 locations scattered around the reservoir. If left untreated, these riverine systems will be continued sources of plant fragments to downstream waters.

Chemical management of submersed invasive aquatic plants in areas of high water exchange is challenging due to the reduced herbicide concentration and exposure time (CET) surrounding target plants, as chemicals are diluted by untreated water. That is, insufficient CET reduces herbicide efficacy (Netherland et al. 1991b; Netherland and Getsinger 1992; Netherland et al. 1993). The use of herbicide combinations may provide a synergistic effect to improve efficacy in areas where water exchange dilutes aqueous herbicide concentrations (Getsinger et al. 1996a). Concurrent applications of herbicide and an inert tracer dye are routinely used to determine bulk water exchange patterns and predict herbicide dissipation under field conditions (Turner et al. 1994; Fox et al. 2002; Wersal and Madsen 2011). Measuring these factors is expected to elucidate treatment efficacy (Netherland et al. 1991b; Netherland and Getsinger 1992; Getsinger et al. 1996b; Getsinger and Netherland 1997).

Objectives

In an effort to evaluate potential herbicide options for controlling Eurasian watermilfoil , a series of field trials was conducted in selected areas of Fort Peck Lake, MT. Site-specific treatment approaches were chosen to determine if Eurasian watermilfoil can be controlled under a variety of environmental conditions common to Fort Peck Lake and to provide management guidance to the Fort Peck Project Office.

Description and impacts of Eurasian watermilfoil

Eurasian watermilfoil is a submersed aquatic plant in the Haloragaceae family, and the following descriptive information is a summary from Madsen (2009). It is rooted at the bottom of fresh-water bodies and produces leaves whorled in groups of four. Leaves are 2 to 4.5 centimeters (cm) long and divided into 14 to 24 pairs of delicate leaflets. Root crowns store carbohydrates during the winter and give rise to stems that can grow to 7.5 meters (m) from the bottom of the water body to the water surface. Profuse branching typically occurs within the first meter of the water surface. Flowers are borne in spikes that emerge above the surface of the water. They are typically 5 to 20 cm long with separate female and male flowers on the same stem. Eurasian watermilfoil reproduction is primarily from plant fragments and root crowns. Natural wind and wave action facilitate dispersal of plant fragments; however, recreational activities such as boating are considered more common mechanisms of dispersal. Germination is erratic as fruits have a thick surface that inhibits germination; thus, seedlings are rarely seen in nature. Despite cold winter conditions in Montana and other northern states, Eurasian watermilfoil is capable of overwintering under ice and rapidly emerges in the spring, often before native plants. Stems typically grow to the surface of the water where profuse branching occurs that can result in *topped out* conditions across large areas of a water body.

Dense growth of Eurasian watermilfoil is known to deleteriously affect a range of ecological, recreational, and aesthetic values of a water body (Madsen 2009). For example, dense growth of Eurasian watermilfoil reduces the abundance of native aquatic plants (Boylen et al. 1999), disrupts water chemistry parameters such as pH and dissolved oxygen (Carpenter and Lodge 1986; Frodge et al. 1990), and alters nutrient cycling (Prentki et al. 1979).

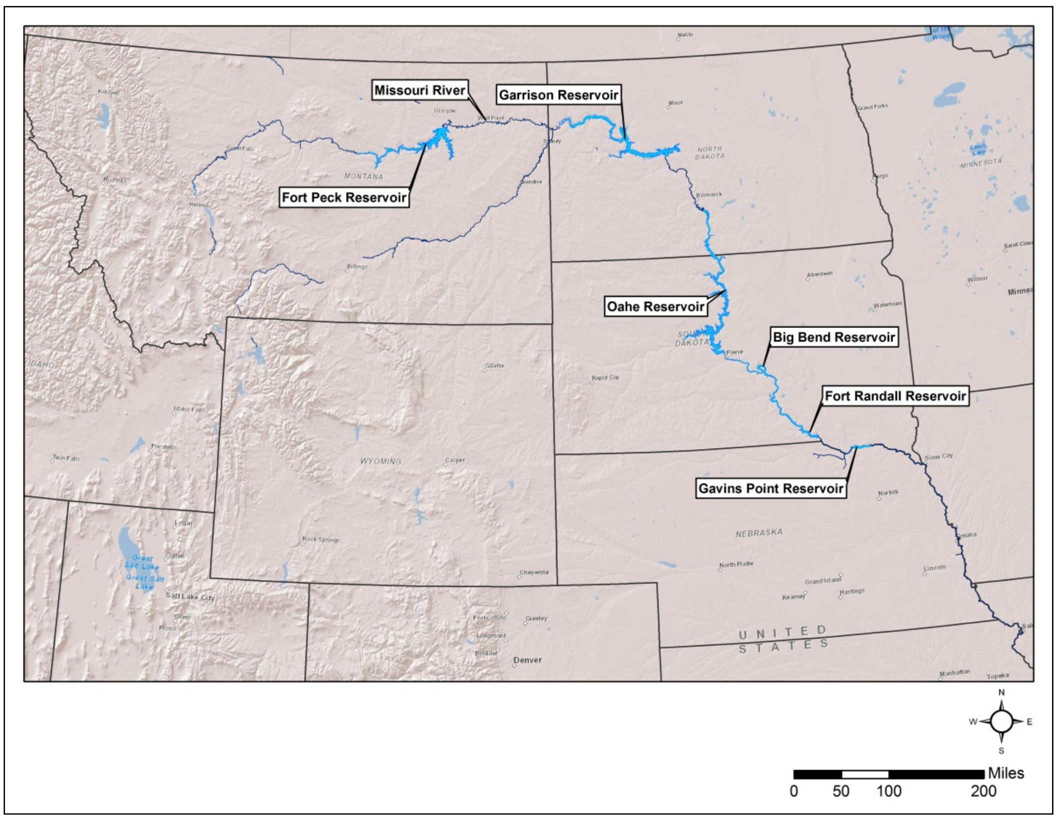
Montana Department of Agriculture lists Eurasian watermilfoil as a Priority 1B noxious weed, meaning it has limited presence in Montana, and management criteria will require eradication or containment and education (MDA 2010). Additionally, the counties surrounding Fort Peck Lake are now considered part of the Upper and Lower Missouri River Eurasian Watermilfoil Management Area in an effort through the education of boaters and inspection of watercraft and trailers leaving the infested water bodies to help prevent the spread of Eurasian watermilfoil.

Fort Peck Lake

Geography and landscape

Fort Peck Dam and Lake is a U.S. Army Corps of Engineer (USACE) project authorized in 1933 by the Public Works Administration and completed in 1940. It is the largest hydraulically filled dam in the world and the second largest dam in the United States. It is the farthest upstream impoundment along the upper Missouri River Basin. The dam is located at river mile (RM)[1] 1,771.5 in northeastern Montana (Figure 1). At maximum operating pool (2,250 feet (ft) mean sea level (MSL)[2]), the surface area of Fort Peck Lake is approximately 100,810 hectares (ha) (249,000 acres) with approximately 2,446 kilometers (km) (1,520 miles) of shoreline . At normal conservation pool (2,234 ft MSL) the lake is 99,595 ha (246,000 acres). As with most reservoirs, surface acreage is highly influenced by pool elevation, driven by hydrologic cycles.

Figure 1. Missouri River Mainstem Reservoir System.



[1] River mile (RM) is a fixed point on U.S. river navigation charts.

[2] Mean sea level (MSL) is the standard unit for reporting lake elevation in U.S. water bodies.

Authorized uses of the Fort Peck Project

The Fort Peck Project was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation.

Hydrology

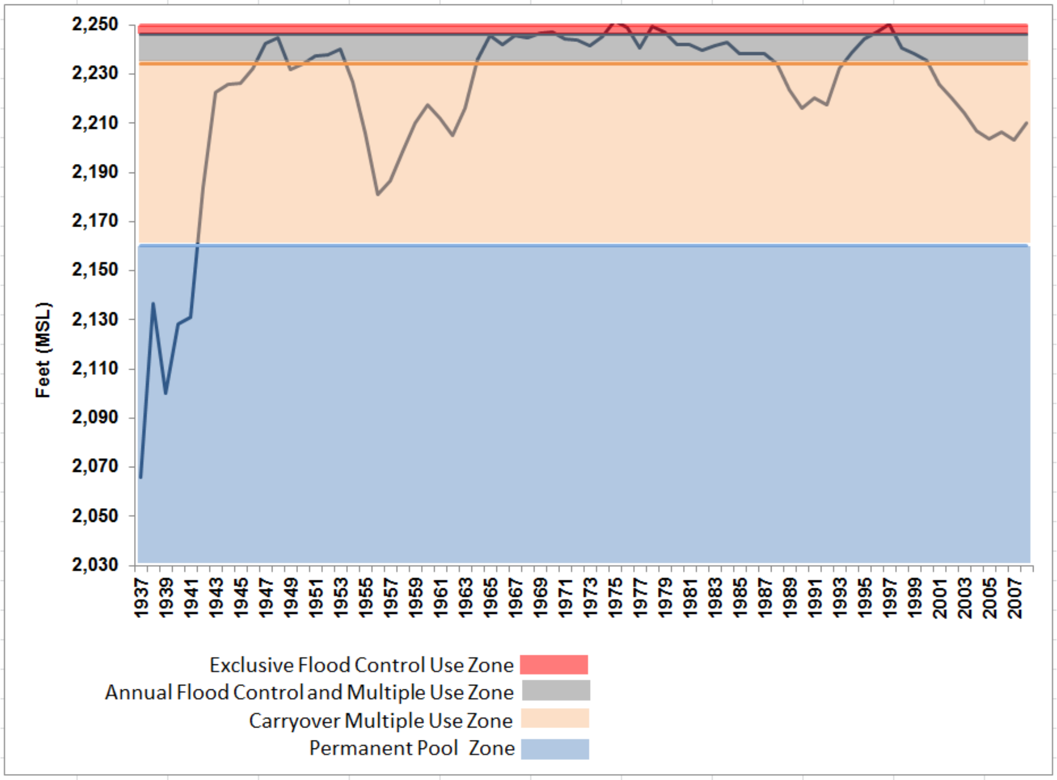
The Missouri River is the primary hydrologic source to Fort Peck Lake, with additional inflow from the Musselshell River and Big Dry Creek. Fort Peck Lake is the first in a series of six USACE dams and reservoirs on the Missouri River, collectively referred to as the Mainstem Reservoir System, operated under guidelines in the Missouri River Mainstem System Master Water Control Manual (Master Manual) (USACE 2006). The Mainstem System is regulated to optimize beneficial uses. To that end, each reservoir in the Mainstem System is divided into four regulation zones:

1. Exclusive Flood Control Zone
2. Annual Flood Control and Multiple Use Zone
3. Carryover Multiple Use Zone
4. Permanent Pool Zone (Figure 2).

The relationship of these zones to surface area, volume, mean depth, and retention time for Fort Peck Lake is provided in Appendix A.

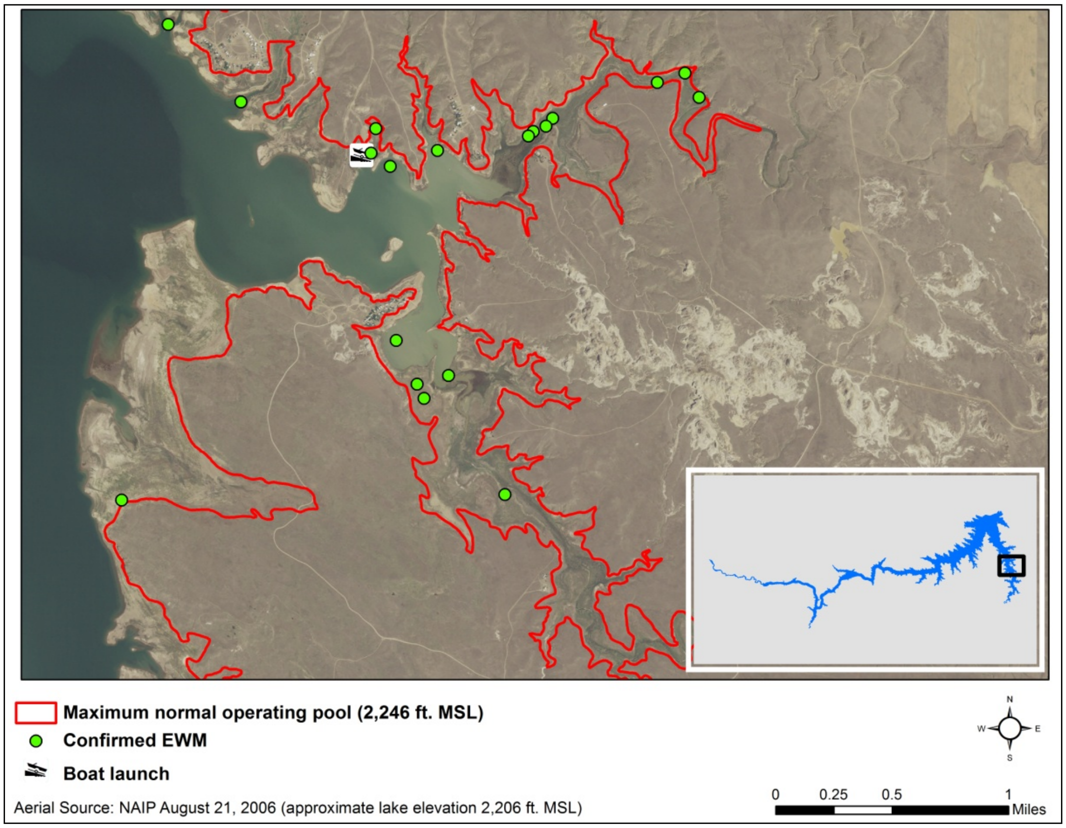
The Exclusive Flood Control Zone refers to the top zone that is reserved to meet flood control requirements and detain water for extreme or unpredictable flood flows. This water is evacuated as rapidly downstream as conditions permit while still serving the overall flood control objective of protecting life and property. The Annual Flood Control and Multiple Use Zone is the *normal operating zone*. This upper portion is reserved annually for the capture and retention of normal and flood runoff and for annual multiple-purpose uses. This storage zone is typically evacuated by 1 March to provide adequate storage for anticipated runoff. The Carryover Multiple Use Zone, often referred to as the *bank account*, provides a storage reserve to support authorized purposes during drought conditions. The Permanent Pool Zone is the bottom zone that is intended to be permanently filled with water, providing sediment storage capacity and minimum pool levels for other authorized purposes (e.g., functionality of irrigation infrastructure, water supply, recreation, water quality, and fish and wildlife).

Figure 2. Flood Control Zones, Fort Peck Lake, MT. Solid line depicts maximum annual lake elevation (feet MSL) since dam construction.



Since 2001, the elevation of Fort Peck Lake has not exceeded the minimum Annual Flood Control and Multiple Use Zone of 2,234 ft MSL. Historic rainfall over the upper basin, in conjunction with heavy snowpack in the mountains and plains in May, June, and July 2011, however, resulted in the highest runoff in 114 years (yr) and a historic maximum for the Exclusive Flood Control Zone in the mainstem system. At Fort Peck Lake, reservoir levels persisted in the Exclusive Flood Control Zone from late May 2011 until the end of July 2011 and in the Annual Flood Control and Multiple Use Zone from August 2011 until August 2012. This resulted in miles of inundated shoreline compared to pre-2011 conditions (Figure 3).

Figure 3. The South Fork Creek area of Fort Peck Lake, MT, depicting an aerial view illustrating low-water year (2006; 2,206 ft MSL) and the maximum normal conservation pool (red line; 2,246 ft MSL) and Eurasian watermilfoil infestations.



Reservoir unbalancing

Reservoir unbalancing is a planned regulation of the system based on computing the percentage of the carryover multiple-purpose pool that remains in Fort Peck, Garrison, and Oahe reservoirs. The purpose of reservoir unbalancing in the three, large upper reservoirs is to benefit reservoir fishery and the listed threatened and endangered (T&E) species protected under the U.S. Endangered Species Act. At each project, the unbalancing would alternate: high one year, float (normal regulation) the next year, and low the third year. Specific reservoir unbalancing schedule and elevation guidelines are provided in the Missouri River Mainstem Reservoir System Master Water Control Manual: Missouri River Basin (USACE 2006). The pulses in pool elevations (Figure 2) could make predictions of Eurasian watermilfoil spread a complex process and would require flexibility in developing and implementing annual treatment strategies.

Water-quality management issues

The Missouri River from Bullwhacker Creek to Fort Peck Lake and Fort Peck Lake (RM 1771.5) itself are on the 303(d) list for impaired water bodies. Specifically, the riverine section is listed impairments to aquatic life, warm water fishery, and drinking water, and the lake is listed for impaired drinking water supply. A total maximum daily load (TMDL) has not yet been completed; however, the primary pollutant/stressors include degraded riparian vegetation, arsenic, and copper. Fort Peck Lake is also on the 303(d) list for impaired drinking water use. Specific pollutants include lead and mercury (that latter has an advisory). Between the Fort Peck Dam and the Montana-South Dakota state line, the Missouri River remains listed for impaired aquatic life, cold water fishery, and warm water fishery due to degraded riparian vegetation, flow regime alterations, and water temperature. Dense stands of Eurasian watermilfoil can negatively impact water quality, particularly temperature, pH, dissolved oxygen, and nutrient cycling (Prentki et al. 1979; Carpenter and Lodge 1986, Frodge et al. 1990; Boylen et al. 1999).

Special status species

Federally listed T&E species that use the aquatic environment are found in the vicinity of the Fort Peck Project. Pallid sturgeon (*Scaphirhynchus albus*) were listed as federally endangered 6 September 1990; interior least tern (*Sterna antillarum*) were listed as endangered in 1985; piper plover (*Charadrius melodus*) were listed as threatened in 1985; and the whooping crane (*Grus americanus*) and black-footed ferret (*Mustela nigripes*) were listed as endangered in 1967.

The preferred habitat requirements for the pallid sturgeon are largely based on information from captured shovelnose sturgeon, a closely related species. In particular, these species prefer low water velocities between 1.3 and 2.9 cubic feet per second (ft^3/sec), and turbid, warm water. Pallid sturgeon are known to feed on small fishes, aquatic insects, and mollusks, and spawning is believed to occur over gravelly or other hard surfaces in May or June (USFWS 2012). The nearest known Eurasian watermilfoil infestation is approximately 26 RM downstream of Beauchamp Creek. Information on direct or indirect impacts of Eurasian watermilfoil on pallid sturgeon life cycles is unknown.

The least tern and piping plover depend on unvegetated sandbars and islands in the river for nesting and are directly affected by water level changes. They typically nest in colonies on river sandbars, sandy shorelines of reservoirs, or in sandpits below the Mainstem System dams, including Fort Peck Dam (USFWS 2003).

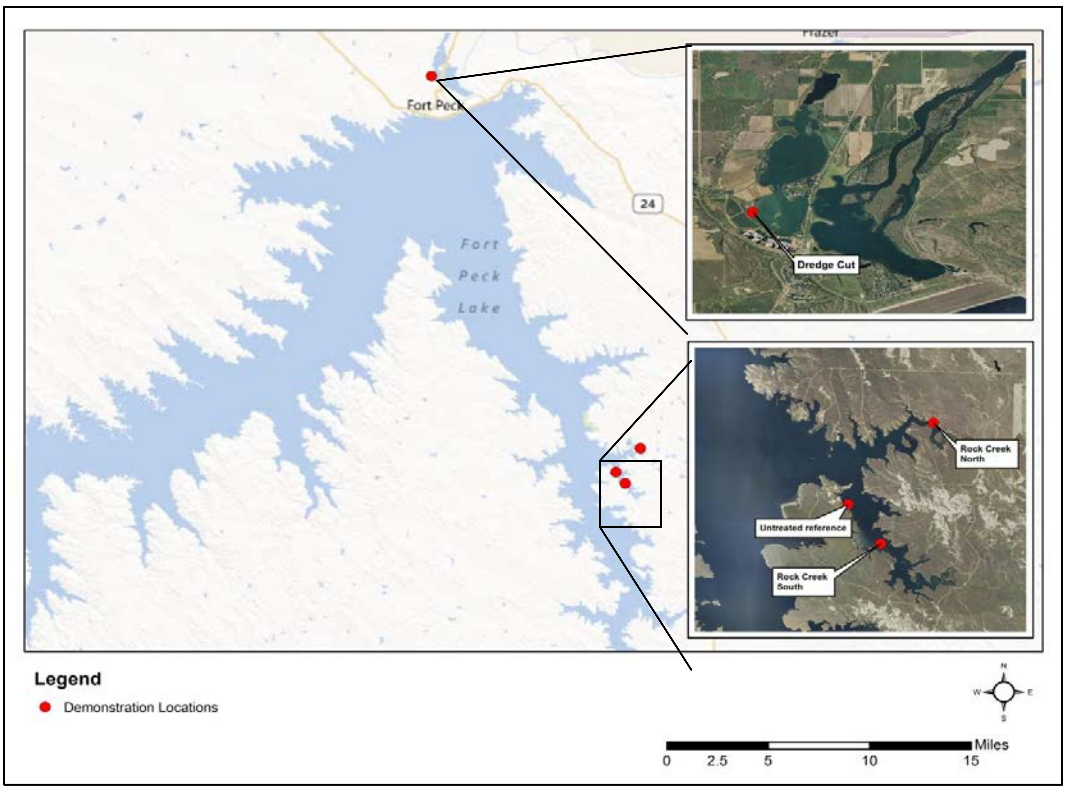
2 Methods

Site selection

Three treatment plots and one untreated reference plot were identified as part of this demonstration of the application of aquatic herbicides to control Eurasian watermilfoil (Figure 4). Plot selection was based on the following parameters:

- known infestation of Eurasian watermilfoil
- access to the site
- proximity to listed species
- ease of installing the barrier curtain.

Figure 4. Locations of herbicide treatment plots and untreated reference plots, Fort Peck Lake, MT, 2012.



The Eurasian watermilfoil infestations in these areas were well established but still relatively *new* populations. The core area of the listed pallid sturgeon is a 98 km reach of the Missouri River between Cow Island (RM 1,944) and Beauchamp Creek (RM 1,883) in the upper reaches of the lake,

approximately 185–320 km upstream from the treatment plots. Public meetings were conducted by project personnel prior to final selection and implementation of the study (Appendix B).

Treatment plot: Dredge Cut

The Fort Peck Dredge Cuts (referred to as Dredge Cut #1 and Dredge Cut #2) are located immediately below Fort Peck Dam (Figure 4). The Dredge Cuts were formed by the excavation of soil for construction of the Fort Peck Dam and are connected to the Missouri River.

A barrier curtain was installed at the Dredge Cut #1 prior to treatment to reduce bulk water exchange behind the barrier during the treatment period in that plot (Figure 5). The curtain (DOT Medium Duty/moving Water Turbidity Curtain, Enviro-USA) consisted of 50, 6 m × 4.1 m deep sections. When sections were connected, a total length of 305 m was achieved. The top of the curtain was buoyed with microfoam floatation devices while the bottom was weighted with galvanized chain ballast. The curtain was towed into position with a boat and anchored at both ends along the shoreline. To stabilize the curtain, a Danforth-style anchor system was deployed at 30 m intervals.

The water intake located behind the barrier was not used for irrigation during or within 72 HAT, as determined by aqueous herbicide concentrations in the plot. The average depth of the Dredge Cut plot was 2.4 m (8 ft) with a surface area of 0.98 ha (4.2 acres).

Treatment plots: Rock Creek South and Rock Creek North

Rock Creek is located along the eastern side of the Big Dry Arm of Fort Peck Lake, approximately 35 km (22 RM) above the Fort Peck Dam (Figure 4). Rock Creek South was 3.24 ha (8 acres) with an average depth of 2.4 m (7.7 ft). Rock Creek North was 2.6 ha (6.4 acres) with an average depth of 1.8 m (6 ft).

Untreated reference plot

The reference plot was also located in the Rock Creek portion of the Big Dry Arm of Fork Peck Lake (Figure 4). This plot was approximately 365 m south of the Rock Creek Marina and is 2.2 ha (5.5 acres) with an average depth of 1.8 m (6 ft). Eurasian watermilfoil growing in the reference plot was similar to that found in Rock Creek South.

Figure 5. Barrier curtain deployed at the Dredge Cut plot, Fort Peck Lake, MT, 2012. The herbicide application was conducted behind the barrier, from center of photo to shore on left.

Pretreatment assessments

An assessment of plant density was conducted pretreatment and 4 and 50 WAT using the quantitative point-intercept method (Madsen 1999). A 25 m grid within the treatment areas was established prior to treatment. At each grid point, a double-sided thatch rake attached to a pole was slowly lowered and twisted one full turn. Each plant species observed was recorded and ranked on a scale of 0 to 5 (0 = no plants to 5 = surface canopy of vegetation at the grid point). This is an effective and repeatable method to evaluate plant density before and after treatment.

Shoots of Eurasian watermilfoil growing in the Dredge Cut were approximately at middepth in the water column. Plant density was somewhat sparse compared to other plots (Figure 6). Other aquatic plant species observed in the Dredge Cut included sago pondweed (*Stuckenia pectinata*), Canadian waterweed (*Elodea canadensis*), water celery (*Vallisneria americana*), cattail (*Typh*a spp.), white water-buttercup (*Rannunculus aquatilis*), and muskgrass (*Chara* spp.).

Figure 6. Example of typical Eurasian watermilfoil density in the Dredge Cut plot, Fort Peck Lake, MT, 2012.

Eurasian watermilfoil in the Rock Creek South treatment plot and the untreated reference plot was observed growing *topped out* (from the sediment to the surface of the water column) throughout much of the area (Figure 7). No other plant species were recorded at this site. Eurasian watermilfoil growing in Rock Creek North was topped out in some, but not all, areas of the plot (Figure 8). Sago pondweed, muskgrass, and Canadian waterweed were also observed at this site. Rankings of plant densities in all plots are provided in the Results and Discussion in Chapter 4.

Herbicide products

The dipotassium salt of endothall (liquid formulation of Aquathol K) was used alone and in combination with the amine formulation of triclopyr (liquid formulation of Kraken), to selectively control Eurasian watermilfoil in three plots in Fort Peck Lake. Both products are approved for aquatic site use in Montana and were evaluated in the *Environmental Assessment and Findings of No Significant Impact: Control of Eurasian Watermilfoil, Fork Peck Project Area, Various Counties, MT* (USACE 2011) against listed species found in Montana waters. Concurrent applications of the inert fluorescent dye, rhodamine WT (RWT), were applied with the herbicides in three plots to determine bulk water exchange patterns and herbicide dissipation under field conditions.

Figure 7. Example of Eurasian watermilfoil density typical of the Rock Creek South plot and the untreated reference plot, Fort Peck Lake, MT, 2012.

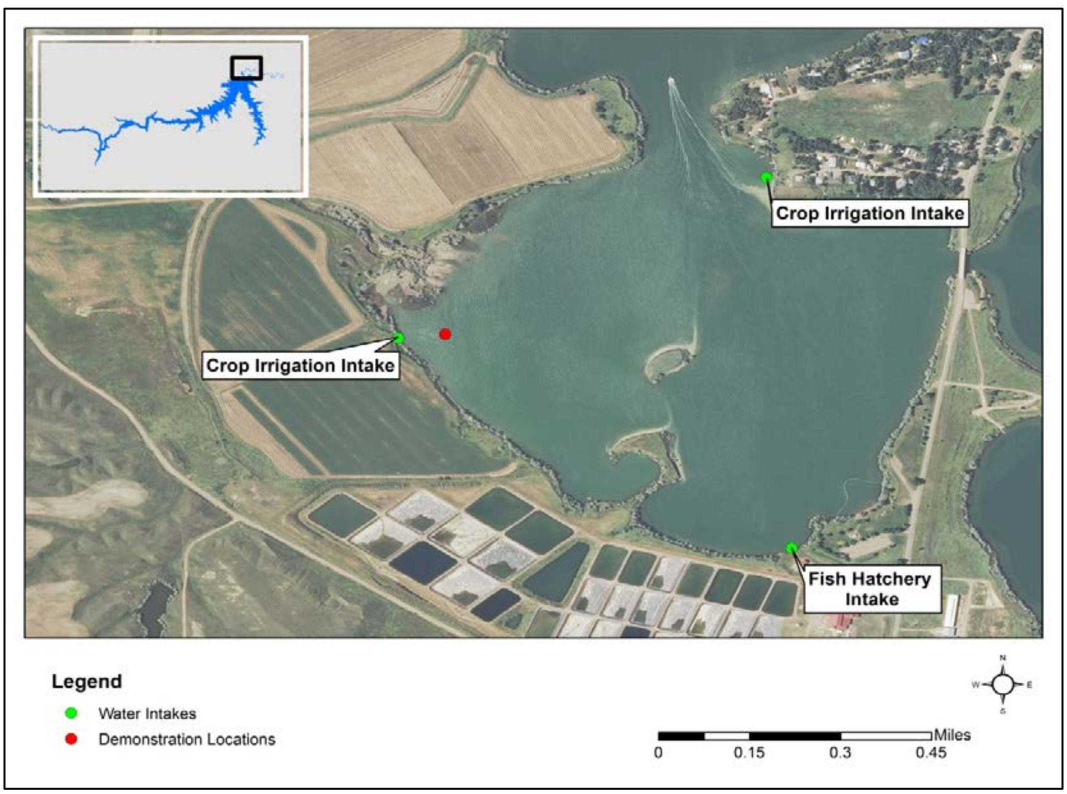
Figure 8. Example of Eurasian watermilfoil density typical of Rock Creek North plot, Fort Peck Lake, MT, 2012.

All use restrictions (Federal and State) on the herbicide labels were employed, which included potable water and irrigation set-back distances per label specific requirements. There are no restrictions on swimming or fishing in waters treated with these herbicides. There were no potable water intakes within 183 m (600 ft) of any plots treated with endothall, per label restrictions. There were no functioning potable water intakes within 488 m (1,600 ft) of any plots treated with triclopyr, per label restrictions. All required permits for the herbicide applications were obtained by the Fort Peck Project Office, and coordination of the trials was conducted with all appropriate State agencies. Herbicide-specific use restrictions are provided in Appendix C.

Three water intakes are located in the vicinity of the Dredge Cut:

1. One is used for crop irrigation and is located within the barrier.
2. A second provides water for the Montana Fish, Wildlife, and Parks fish hatchery and is approximately 815 m (2,680 ft) southeast of the treatment area.
3. The third is used for crop irrigation and is located approximately 785 m (2,580 ft) northeast of the treatment area (Figure 9).

Figure 9. Location of water intakes (green dots) in relation to the Dredge Cut plot, Fort Peck Lake, MT, 2012.



The intakes outside of the barrier were well within set-back distance restrictions imposed by the herbicide labels. As an extra precaution, no intakes were in operation at the time of treatment, and none are used as potable sources.

Water intake structures are located in the Rock Creek area; however, they were at least 915 m (3,000 ft) away from the nearest treatment site, and/or they are nonpotable water intakes (Figure 10 and Figure 11).

Figure 10. Nonpotable water intake (green dot) associated with Rock Creek South plot, Fort Peck Lake, MT, 2012.

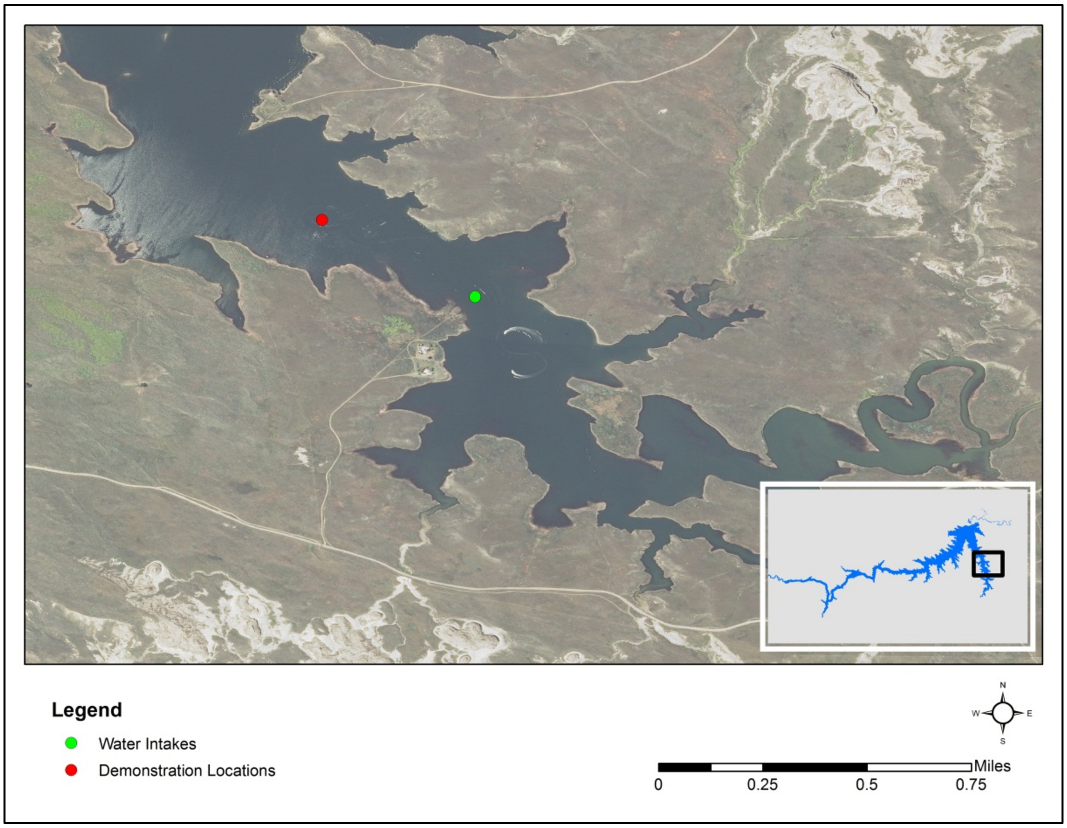
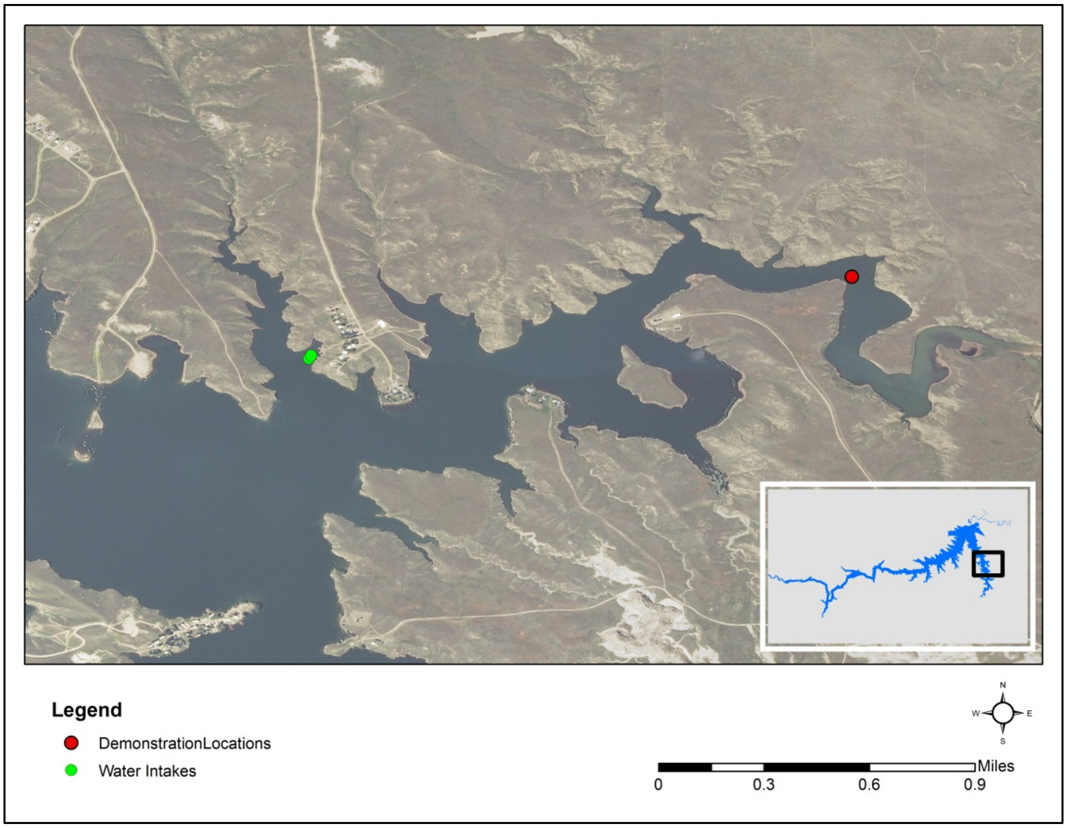


Figure 11. Nonpotable water intakes (green dots) associated with Rock Creek North plot, Fort Peck Lake, MT, 2012.



Treatment schedule and rates

Herbicide application rates for this study were selected based on results from previous growth chamber evaluations (Netherland et al. 1991a; Netherland and Getsinger 1992) and successful field verification trials in eastern Washington State and western Montana (Getsinger et al. 1997; Wersal and Madsen 2011; Getsinger et al. 2013a,b). Treatment dates and nominal herbicide and dye application rates are listed in Table 1. The liquid RWT dye was applied as a tank mix with water combined with endothall using a variable-depth injection system (LittLine), Clean Lakes, Inc., Coeur d'Alene, ID). This application process simulated an operational-scale liquid aquatic herbicide application, with the injection system calibrated to deliver product to the middle to lower portion of the water column. Where the application of two products that cannot be mixed is needed, two tanks allow for the application of two separate aquatic herbicides simultaneously at different application rates. Herbicides were applied in approximately 15 m (50 ft) wide swaths as the boat traveled 5 to 6.5 kilometers per hour (kph) (3 to 4 miles per hour (mph)).

Table 1. Treatment dates, herbicide and dye application rates, and sizes and volumes of plots on Fort Peck Lake, MT, 2012.

Plot	Treatment Date	Average Depth m (ft)	Hectares (surface acres)	Cubic Meters (acre-ft)	Treatment	Barrier
Dredge Cut	17 Aug 12	2.4 (8.0)	0.98 (4.2)	41,938 (34)	2,000 µg/L Endothall + 10 µg/L dye	Yes
Rock Creek South	20 Aug 12	2.4 (7.7)	3.24 (8.0)	76,476 (62)	2,500 µg/L Endothall + 2,000 µg/L Triclopyr + 10 µg/L dye	No
Rock Creek North	22 Aug 12	1.8 (6.0)	2.60 (6.4)	46,872 (38)	2,000 µg/L Endothall + 2,000 µg/L Triclopyr + 10 µg/L dye	No
Untreated Reference	17 Aug 12	1.8 (6.0)	2.30 (5.5)	40,705 (33)	N/A	No

Water exchange was determined by measuring RWT dye using an in situ with fluorometric instrumentation. The RWT dye is approved by the U.S. Environmental Protection Agency (USEPA) for use in surface waters. At the nominal aqueous concentrations used for this study, ≤10 micrograms per liter (µg/L) (parts per billion) (ppb)), RWT dye is harmless to humans, fish, and wildlife. This dye is routinely used in water tracing studies in the Pacific Northwest by Federal and State agencies. At concentrations used, the pink hue of the dye is practically invisible to the naked eye but can be measured using calibrated fluorometers to a level of 0.1 µg/L. Additional information on RWT dye use in surface waters is presented in Appendix D.

The Dredge Cut plot was treated on 17 August 2012. At the time of treatment, winds were calm, skies were clear, and the lake was at 2,234.92 MSL (though this plot is not directly affected by reservoir operations). Rock Creek South was treated the morning of 20 August 2012. The winds were calm, and the sky was clear; however, variable winds from the south increased as the day progressed and shifted from north by 8 HAT. Rock Creek North was treated on 22 August 2012. At the time of treatment, winds were light and out of east, switching to northwest within 6 HAT. All plots were treated at approximately 7:45 a.m., and fewer than 45 minutes elapsed for each treatment.

Additional analysis

Water quality

Three YSI datasondes (YSI, Yellow Springs, OH)) were suspended midwater column at three locations within each treatment plot prior to herbicide application. Each datasonde logged dissolved oxygen (DO), pH, and RWT dye concentration every 15 minutes through 48 HAT. Each unit was calibrated before and after deployment per manufacturer's recommendations. However, in the Rock Creek North treatment plot, the DO probes on two datasondes malfunctioned during the collection period; thus, DO data for this plot are restricted to that collected from one datasonde. One DO probe also malfunctioned in the Rock Creek South treatment plot; thus, DO data for this plot are restricted to the average values from two datasondes.

Dye and herbicide sampling and analysis

In addition to measuring dye using the datasondes, concentrations were measured at five predetermined *permanent* locations within the treatment plots (Figure 12). Measurements were recorded at 30.5 cm (1 ft) below the surface, mid-depth, and 30.5 cm above the bottom using a hand-held Turner Designs Cyclops-7 submersible fluorometer (Sunnyvale, CA). Measurements were taken immediately after treatment, and nearly every HAT up to 6 days after treatment (DAT), depending on the plot (Table 2).

Water samples were collected at the same five locations and analyzed for herbicide concentration (endothall and triclopyr); however, these samples were collected on a more conservative schedule than the dye data (Table 2). Water was collected in 60 millileter (ml) opaque, high-density polyethylene (HDPE) bottles and acidified (pH <4) with muriatic acid to preserve the sample for future analysis. Samples were transported to the University of Florida Center for Aquatic and Invasive Plants, Gainesville, FL, for analysis. Endothall and triclopyr were analyzed via the use of enzyme-linked immunoassay kits manufactured by Modernwater Inc. (New Castle, DE). The kit platform for both endothall and triclopyr and the equipment for reading results were similar to that described for the fluridone by Netherland et al. (2002). Absorbance was measured using an RPA-II Rapid Analyzer (Modernwater Inc., New Castle, DE). Analysis of four standards provided with each kit was used to establish the calibration curve. Along with an internal standard provided with the immunoassay kit, a series of external endothall standards (500, 1000, and 2000 µg/L) and triclopyr

standards (250, 500, and 1000 µg/L) were analyzed with each run to quantify accuracy of the analysis. The average recovery for internal and external standards ranged from 93% to 105% for endothall and 88% to 111% for triclopyr. The lower detection limits for endothall and triclopyr were 7 and 0.1 µg/L, respectively. For each treatment site, sample data within the treatment plot were combined, and a linear decay model was used to provide a first-order dissipation half-life of endothall and triclopyr.

Figure 12. Permanent sample locations at the Dredge Cut, Rock Creek South and Rock Creek North plots, Fort Peck Lake, MT, 2012.

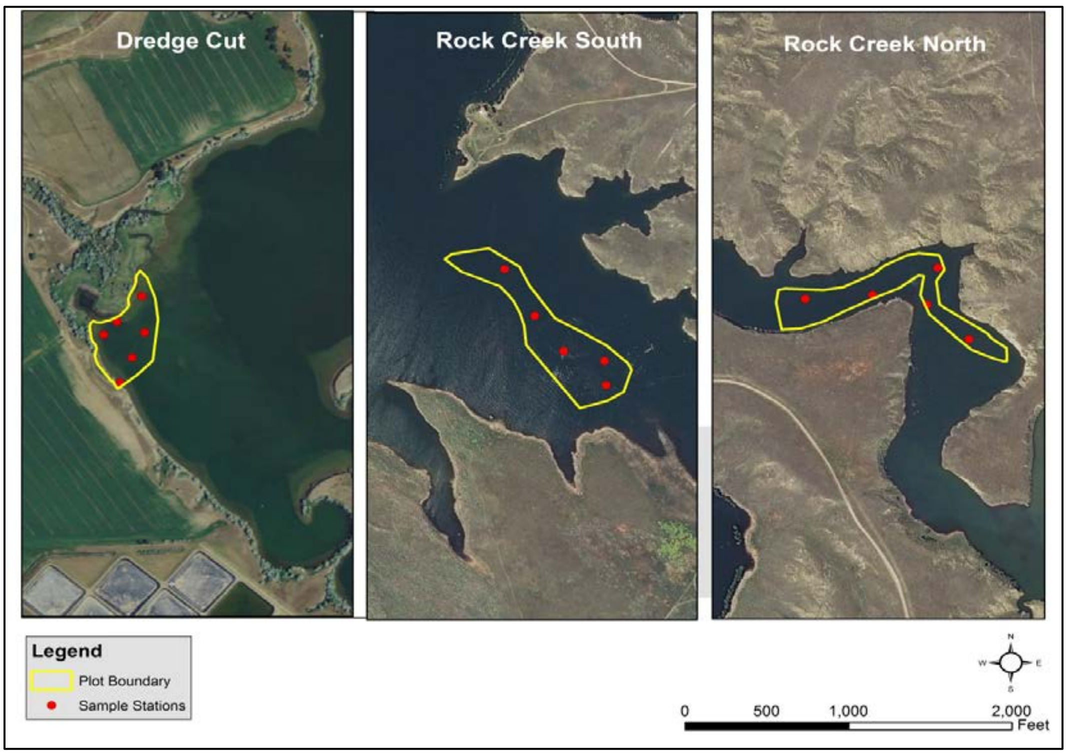


Table 2. Dye and herbicide sample collection schedule for treatment plots on Fort Peck Lake, MT, 2012.

Plot	HAT												DAT			
	0	1	2	3	4	4.5	6	8	24	27	30	46	2	3	4	6
Dredge Cut	• Δ	• Δ	•	• Δ	•		• Δ	•	• Δ				• Δ		•	•
Rock Creek South	• Δ	• Δ	• Δ	•		•	• Δ	• Δ		• Δ	•		•	•		
Rock Creek North	• Δ	• Δ	•	• Δ	•		• Δ	• Δ		• Δ		• Δ				

HAT = hours after treatment; DAT = days after treatment

• = dye was measured at each of the five stations

Δ = sample was collected for herbicide analysis from each of the five stations

Spatial distribution of dye

Two-dimensional (2D) illustrations of dye concentrations were modeled for the top (surface), middle, and bottom of the water column for select times after treatment. Model inputs included field-derived dye concentrations from the five permanent locations within each treatment plot collected at the surface, middle, and bottom of the water column. Point data, including the sample locations and the treatment boundaries, were first transformed from the Geographic Coordinate System WGS 1984 to North American Datum 1983 State Plane Montana Feet. Using Spatial Analyst extension tools in ArcMap 10.0 (ESRI, Redlands, CA), the raster surface representing dye concentrations throughout the treatment area was spatially interpolated from the point data using the natural neighbor approach. The surface was created with a 1 ft pixel size, and the modeled data were limited to a bounding polygon (e.g., treatment area). The symbology settings used to display the surface were defined as concentration intervals of 1 µg/L associated with a color ramp from green (low dye concentration) to red (high dye concentration).

Post-treatment plant assessment

Plant density was assessed 4 WAT (19 and 20 September 2012) using previously described methods. At that time, water temperature was 58.2 °C in the Dredge Cut and 62.8 °C in the lake. Lake elevation was 2,232.5 ft MSL, compared to 2,234.9 ft MSL during treatment, leaving some sample points within Rock Creek inaccessible. Plant density was also assessed at 50 WAT (5 and 6 August 2013) using previously described methods. At that time, water temperature was 20.1 °C in the Dredge Cut, and 20.4 °C in the lake. Lake elevation at 50 WAT was 2,226.1 ft MSL, compared to 2,234.9 ft MSL during treatment in 2012, an unexpected decline in lake level of 2.7 m (8.8 ft). In addition, the lake elevation reached a minimum level during that period of 2222.2 ft MSL, a decline of over 3.8 m (12.7 ft). Since Fort Peck Lake is the uppermost reservoir on the Missouri River, fluctuations in depth of annual snow pack and timing of annual snow melt in its watershed can greatly impact seasonal lake-level elevations and exact predictions of lake levels. This prolonged drawdown began in early fall and persisted throughout the following the winter and summer months, leaving many sample points within the Rock Creek plots in very shallow water and inaccessible at the 50 WAT sampling period (59.6% of the plot in Rock Creek South, 83.3% in Rock Creek North, and 72% in the Reference site). Aquatic plant species not found in the pretreatment or 4 WAT plant assessments included leafy pondweed (*Potamogeton foliosus*) and horned pondweed (*Zannicchellia palustris*).

3 Results and Discussion

Environmental conditions

At the time of treatment (conducted between approximately 7:40 a.m. to 8:30 a.m. across all sites), the average water temperature in the Dredge Cut was 18.8 °C, 20.8 °C in Rock Creek South, and 22.3 °C in Rock Creek North (Table 3). Mean DO concentration was 7.3 milligrams per liter (mg/L) in the Dredge Cut, 7.5 mg/L in Rock Creek South, and 7.3 mg/L in Rock Creek North. Across all plots, pH ranged from 9.1 to 9.2. As previously mentioned, winds were calm and skies were clear during treatment at the Dredge Cut. At Rock Creek South, skies were clear and southeast winds were approximately 10 kph during treatment. At Rock Creek North, skies were overcast, but winds were calm.

Table 3. Temperature, dissolved oxygen, pH, and wind measured in the study plots at the time of treatment, Fort Peck Lake, MT, 2012.

Plot	Temperature (°C) (Min to Max)	Mean Dissolved Oxygen (mg/L) (Min to Max)	Mean pH (Min to Max)	Wind	
				Speed (kph)	Direction
Dredge Cut	18.7 to 18.9	7.04 to 7.62	9.0 to 9.1	3	N
Rock Creek South	20.6 to 22.9	7.3 to 7.9	9.2	10	SE
Rock Creek North	22.3	7.3	9.2	0	N/A

Following treatment, the average water temperature in the Dredge Cut was 20.0 °C, 21.6 °C in Rock Creek South, and 22.4 °C in Rock Creek North (Table 4). Mean DO in the Dredge Cut was 8.2 mg/L, 71 mg/L in Rock Creek South, and 7.3 mg/L in Rock Creek North. Across all plots, pH ranged from 9.1 to 9.2. No major changes in water quality were measured during the post-treatment period. Winds remained calm immediately following treatment at the Dredge Cut. At Rock Creek South, skies remained clear; however, winds shifted to northwest > 10 kph by 8 HAT. At Rock Creek North, skies remained overcast with calm winds immediately following treatment.

Table 4. Temperature, dissolved oxygen, and pH measured in the study plots following treatment, Fort Peck Lake, MT, 2012.

Plot	Temperature (°C) Min to Max	Dissolved Oxygen (mg/L) Min to Max	pH Min to Max	Collected Hours after Treatment
Dredge Cut	18.7 to 21.4	6.3 to 9.3	8.9 to 9.3	55
Rock Creek South	20.5 to 22.6	7.1 to 8.3	9.0 to 9.3	31
Rock Creek North	20.8 to 24.1	6.5 to 7.7	9.1 to 9.3	48

Dye and herbicide concentration

Dredge Cut

Dye concentrations in the Dredge Cut were generally higher at the bottom of the water column, and the highest concentration of 10.8 µg/L was observed 3 HAT, also at the bottom of the water column (Figure 13). Higher levels near the bottom were expected since the application technique targeted the bottom half of the water column. Dye concentration averaged 4.0 µg/L across the plot until the barrier curtain was removed 4 DAT, after which concentrations declined precipitously, and dye was no longer detected 6 DAT. Across the plot, dye was concentrated in the eastern portion of the plot but was more evenly dispersed across the plot within 3 HAT (Figures 14, 15, and 16). Areas immediately outside the barrier curtain were intermittently sampled for dye concentration through 48 HAT. No detections of dye were measured in these outside areas with the exception of the south end of the curtain where 2.1 µg/L were detected at 24 HAT. This area was an anchor point of the curtain near the shoreline and had been opened for 30 minutes to allow for the treatment boat to exit the plot. Similarly, endothall concentration was highest in the bottom of the water column through 1 DAT, with an average concentration of 1,524 µg/L (Figure 17). In general, endothall and dye concentrations were not highly correlated (r = 0.54) at 1 DAT. Water exchange patterns and aqueous herbicide concentrations indicated that an adequate endothall CET relationship was maintained behind the barrier curtain, suggesting that good control of Eurasian watermilfoil in this plot would occur. When the barrier was removed at 3 DAT, water exchange patterns diluted dye levels quickly (within approximately 24 hr). This rapid water exchange pattern suggests that levels of endothall lethal to Eurasian watermilfoil may not have been maintained without the use of the barrier curtain in this plot.

Figure 13. Mean rhodamine WT (RWT) dye concentration (±SE) in the Dredge Cut plot from 0 HAT to 6 DAT, Fort Peck Lake, MT, 2012.

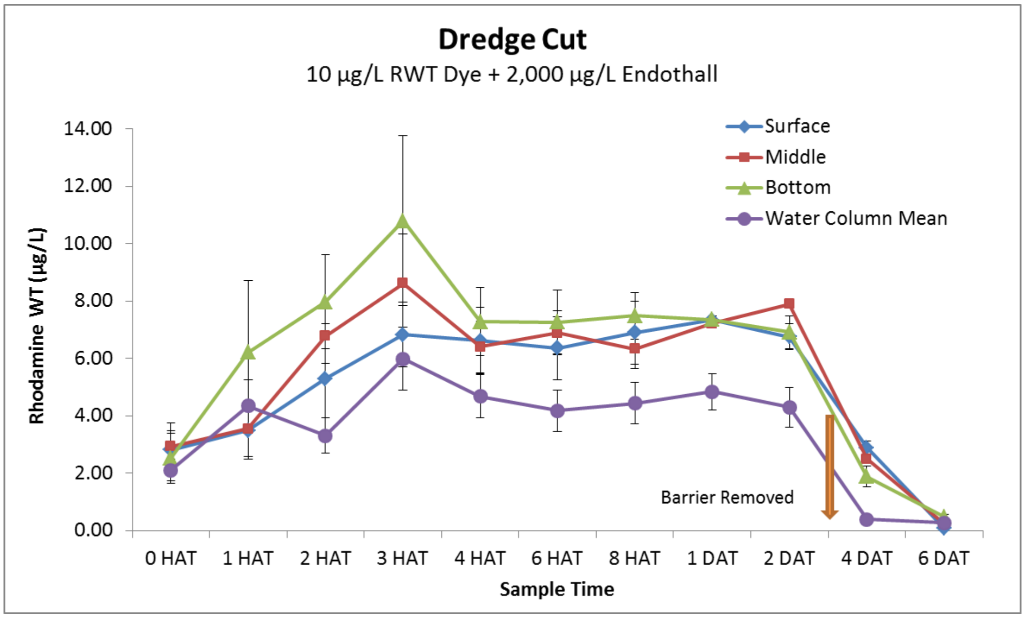


Figure 14. Dredge Cut rhodamine WT dye (µg/L) dissipation patterns 1 HAT at the surface, middle, and bottom of the plot, Fort Peck Lake, MT, 2012.

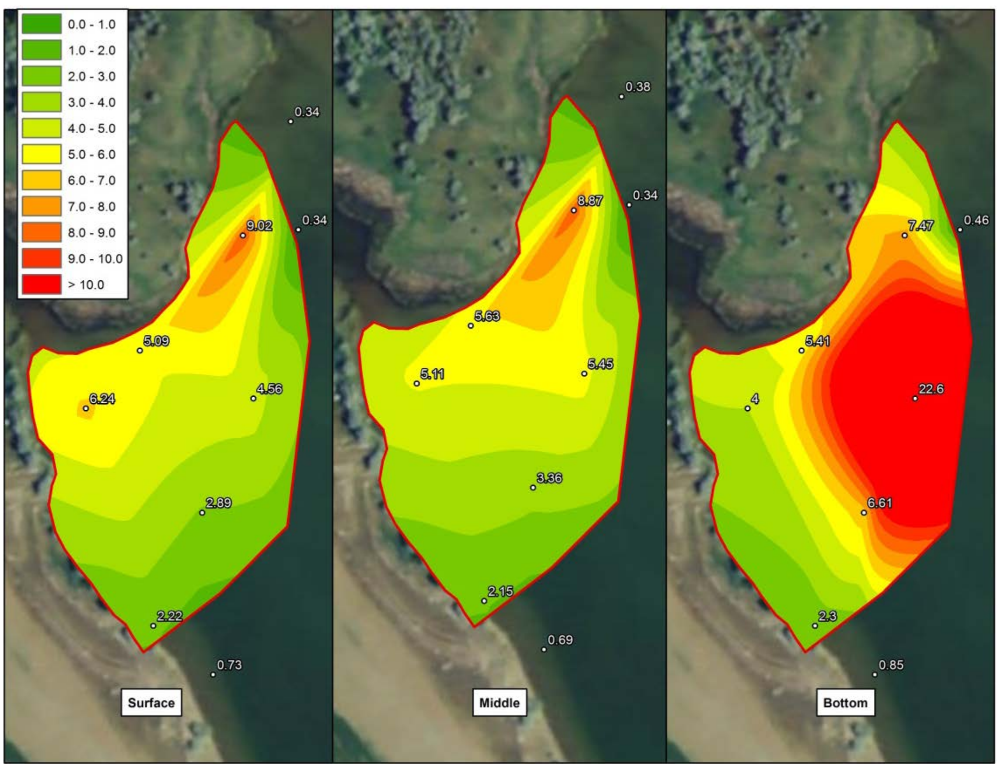


Figure 15. Dredge Cut rhodamine WT dye (µg/L) dissipation patterns 3 HAT at the surface, middle, and bottom of the plot, Fort Peck Lake, MT, 2012.

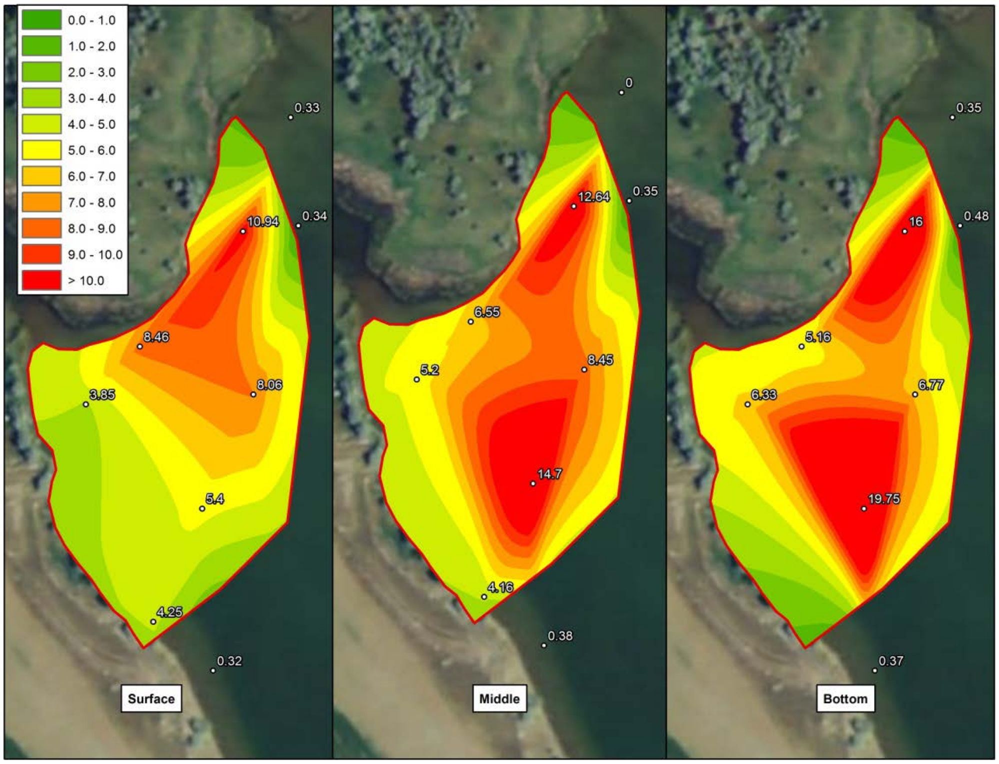


Figure 16. Dredge Cut rhodamine WT dye (µg/L) dissipation patterns 1 DAT at the surface, middle, and bottom of the plot, Fort Peck Lake, MT, 2012.

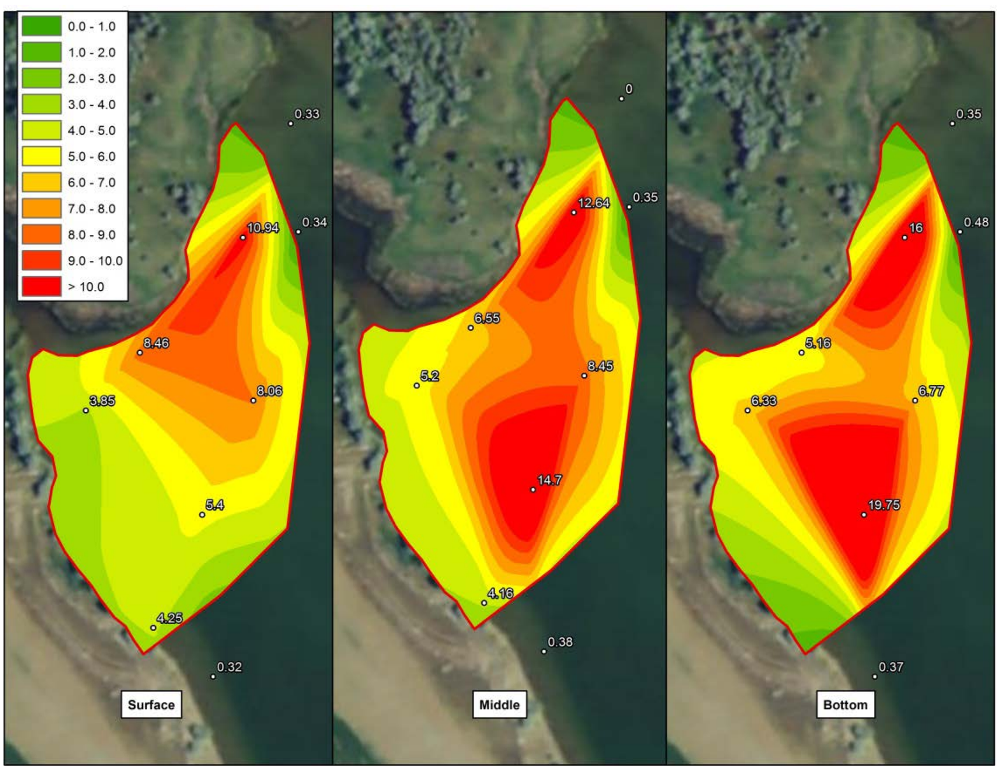
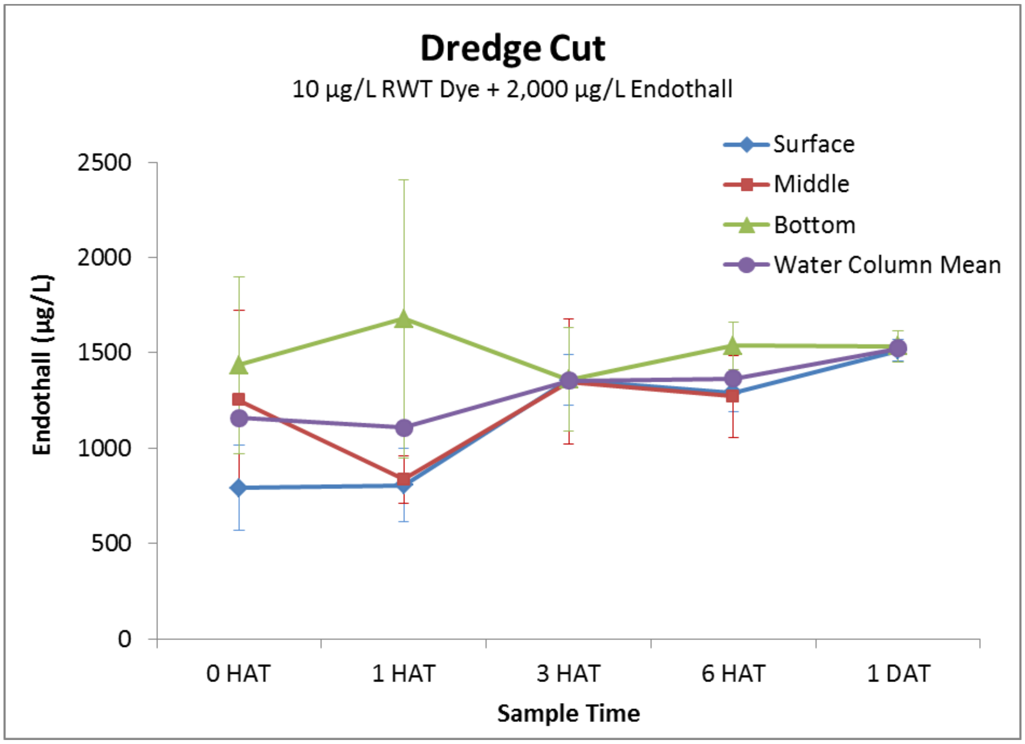


Figure 17. Mean endothall concentration (±SE) in the Dredge Cut plot from 0 HAT to 1 DAT, Fort Peck Lake, MT, 2012.



Rock Creek South

Similar to the Dredge Cut plot, dye levels in Rock Creek South were generally higher at the bottom of the water column; however, the highest concentration was only 6.4 µg/L, measured at 3 HAT (Figure 18). The average dye concentration over the entire plot was ≤ 2.0 µg/L within the first 8 HAT and declined precipitously thereafter. Across the plot, dye was concentrated in the southeast portion of the plot with nearly no detections in the northern portion of the plot throughout the entire evaluation period (Figures 19 and 20).

Endothall concentrations were consistently below 300 µg/L throughout the study period (Figure 21) and was weakly, but positively, correlated with dye concentration ($r = 0.63$). Mean triclopyr concentrations were below 1,000 µg/L throughout the study period and were only 95 µg/L 1 DAT (Figure 22). Triclopyr concentration was positively correlated with dye concentration ($r = 0.76$). Close proximity of the treatment site to the open waters of the Big Dry Arm of Fort Peck Lake resulted in greater water exchange compared to other treatment sites. Therefore, sufficient CET relationships were not achieved to control Eurasian watermilfoil in Rock Creek South.

Figure 18. Mean rhodamine WT (RWT) dye concentration (±SE) in Rock Creek South from 0 HAT to 3 DAT, Fort Peck Lake, MT, 2012.

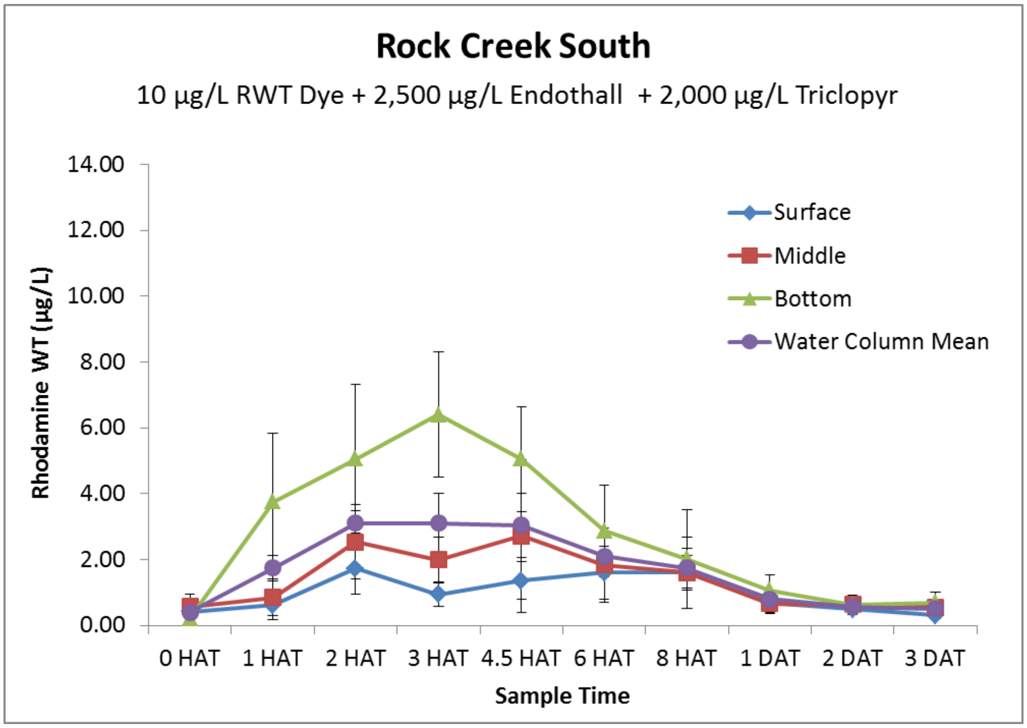


Figure 19. Rock Creek South rhodamine WT dye (µg/L) dissipation patterns 3 HAT at the surface, middle, and bottom of the plot, Fort Peck Lake, MT, 2012.

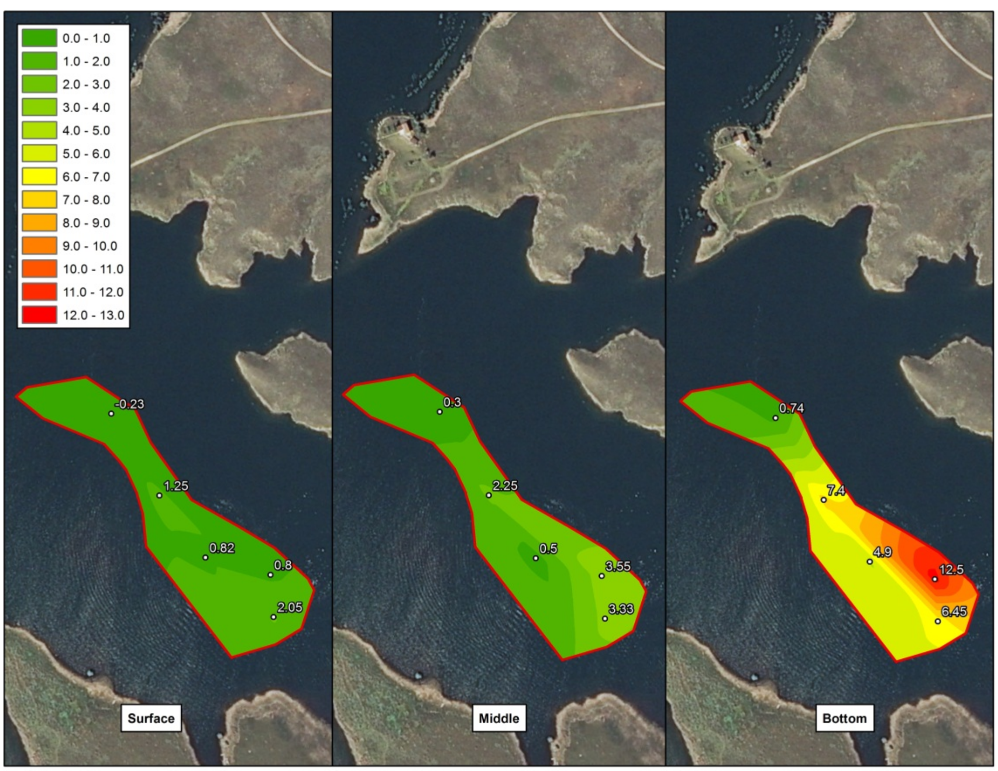


Figure 20. Rock Creek South rhodamine WT dye (µg/L) dissipation patterns 6 HAT at the surface, middle, and bottom of the plot, Fort Peck Lake, MT, 2012.

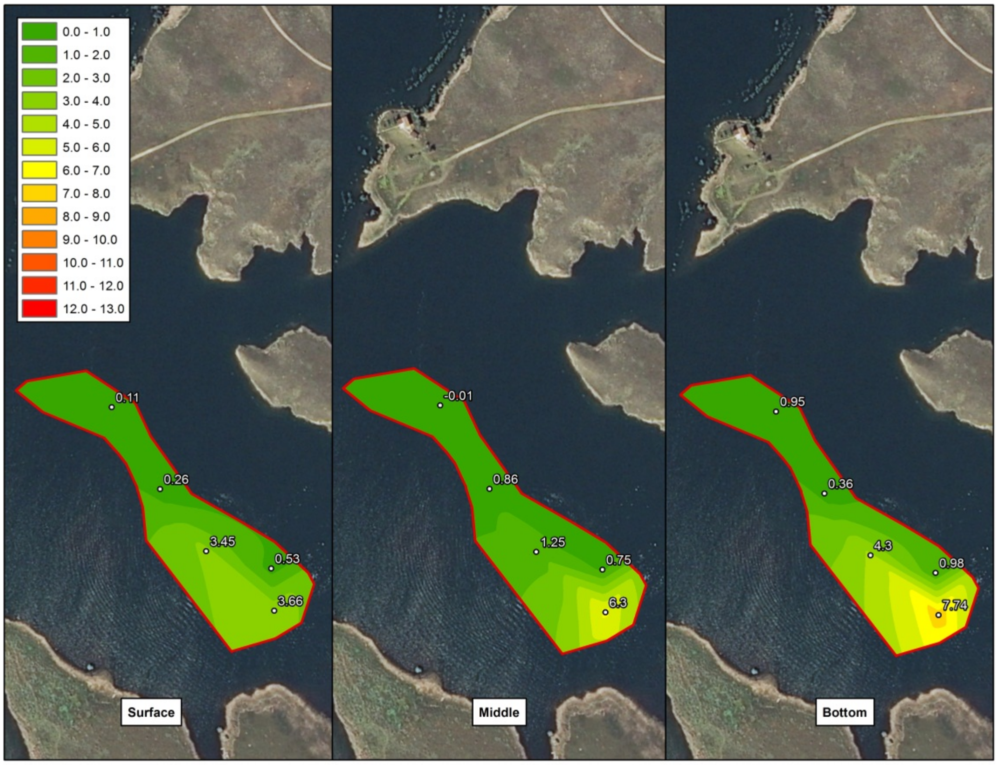


Figure 21. Mean endothall concentration (±SE) in Rock Creek South from 0 HAT to 1 day after treatment (DAT), Fort Peck Lake, MT, 2012.

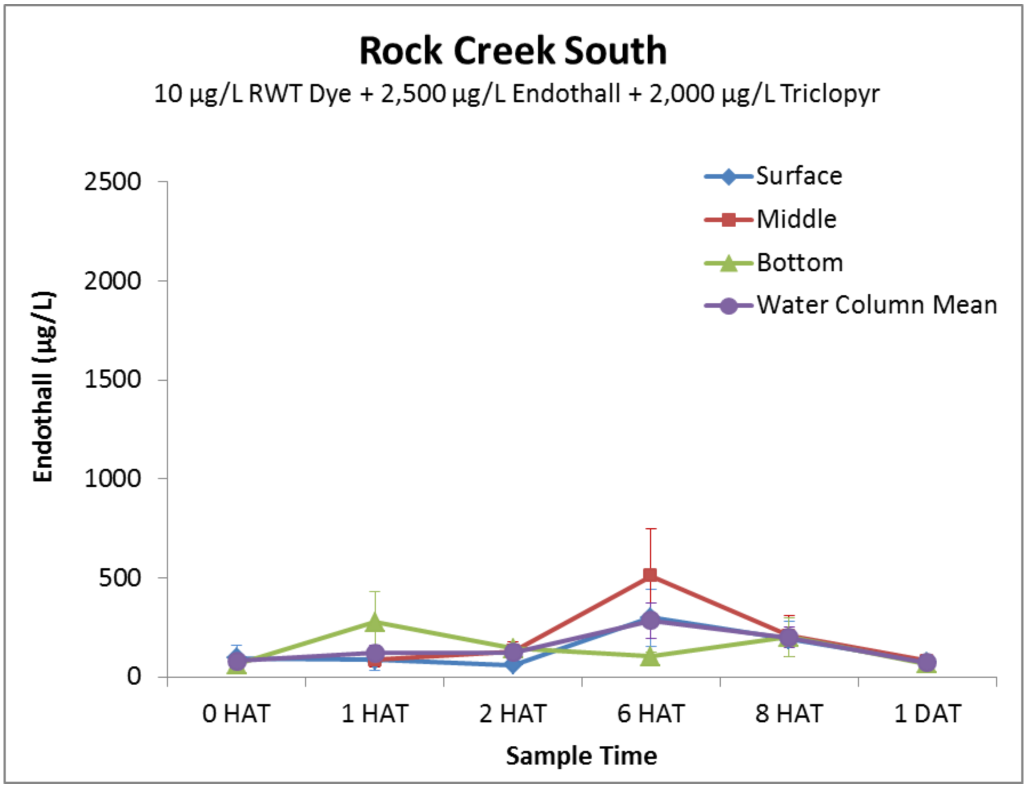
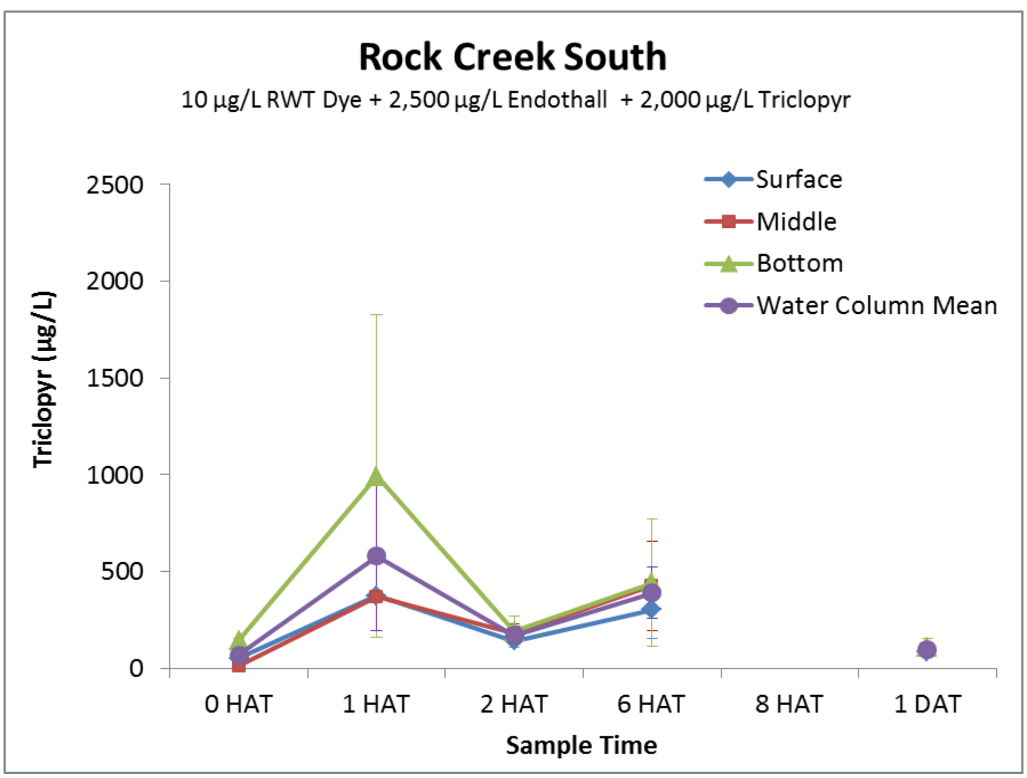


Figure 22. Mean triclopyr concentration (±SE) in Rock Creek South from 0 HAT to 1 DAT, Fort Peck Lake, MT, 2012.



Rock Creek North

Dye concentrations in Rock Creek North were quite uniform between the surface, middle, and bottom of the water column with the highest concentration of 11.7 µg/L at 4 HAT (Figure 23). This similarity is attributed to the shallow water in the Rock Creek North plot. Water depth ranged from only 1.2 to 2.1 m. Dye concentrations steadily declined thereafter, but averaged 6.5 µg/L even 2 DAT. Across the plot, dye was concentrated in the north-central portion of the plot immediately following treatment (Figure 24); however, dye dissipation increased in the eastern portion of the plot but remained quite low in the western portion (Figure 25 and Figure 26). Most likely, increased northwesterly winds prevented sufficient mixing of product into the western portion of the plot.

Similar to dye concentrations, endothall concentrations were quite uniform between the surface, middle, and bottom of the water column with an average concentration of 700 µg/L even 1 DAT (Figure 27). The correlation between endothall and dye concentrations was highest in Rock Creek North (r = 0.86). Triclopyr concentrations in Rock Creek North averaged 785 µg/L throughout the study with little variation immediately following treatment until the final sampling at 1 DAT (Figure 28). Triclopyr was positively correlated with dye concentration (r = 0.82). Water exchange patterns and aqueous herbicide concentrations indicated that an adequate endothall and triclopyr CET relationship were maintained in the plot, suggesting that good control of Eurasian watermilfoil would occur.

Figure 23. Mean rhodamine WT (RWT) dye concentration (±SE) in Rock Creek North from 0 HAT to 2 DAT, Fort Peck Lake, MT, 2012.

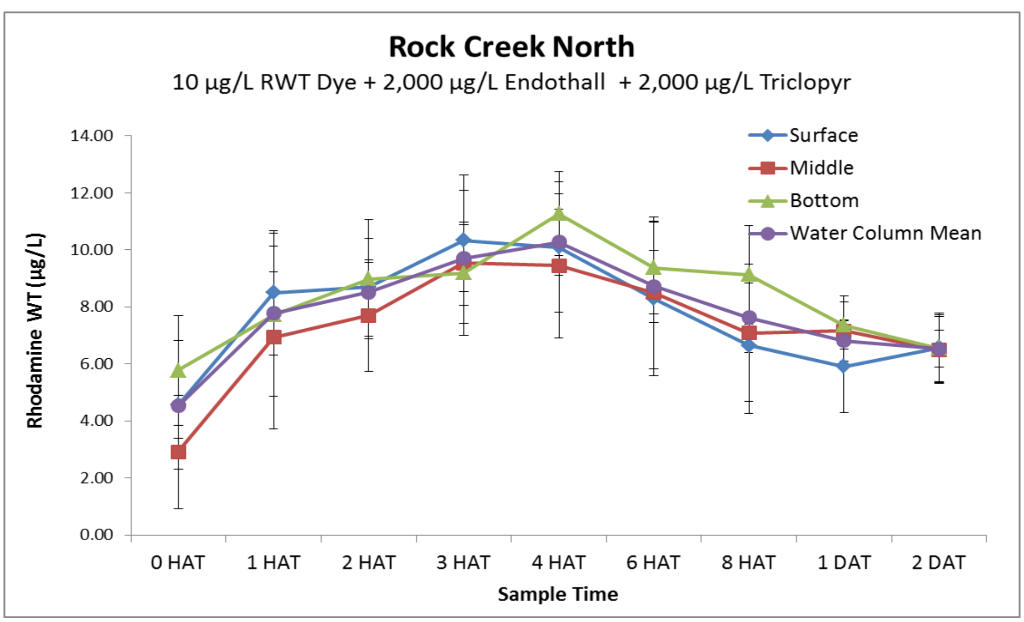


Figure 24. Rock Creek North rhodamine WT dye (µg/L) dissipation patterns 1 HAT at the surface, middle, and bottom of the plot, Fort Peck Lake, MT, 2012.

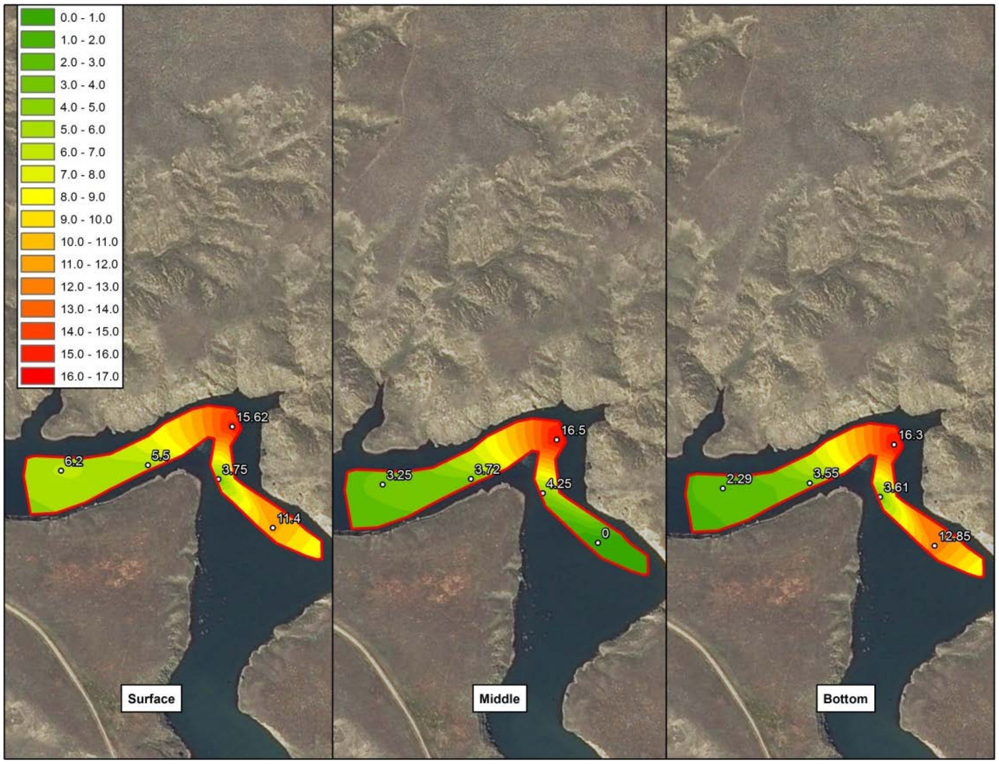


Figure 25. Rock Creek North rhodamine WT dye (µg/L) dissipation patterns 4 HAT at the surface, middle, and bottom of the plot, Fort Peck Lake, MT, 2012.

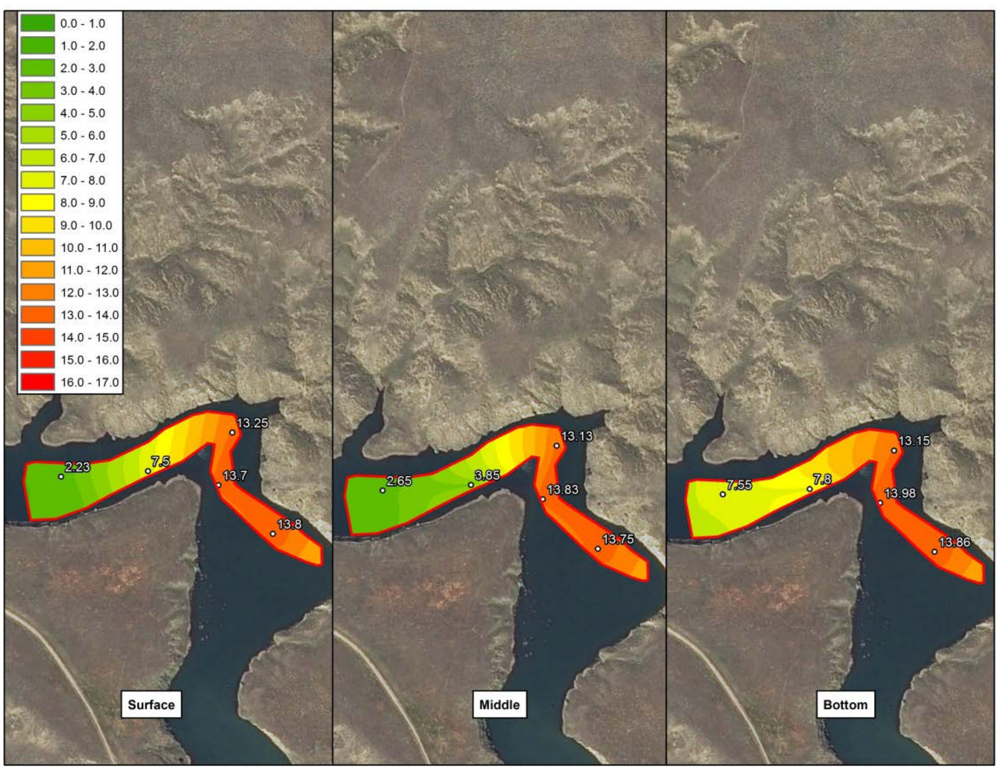


Figure 26. Rock Creek North rhodamine WT dye (µg/L) dissipation patterns 1 DAT at the surface, middle, and bottom of the plot, Fort Peck Lake, MT, 2012.

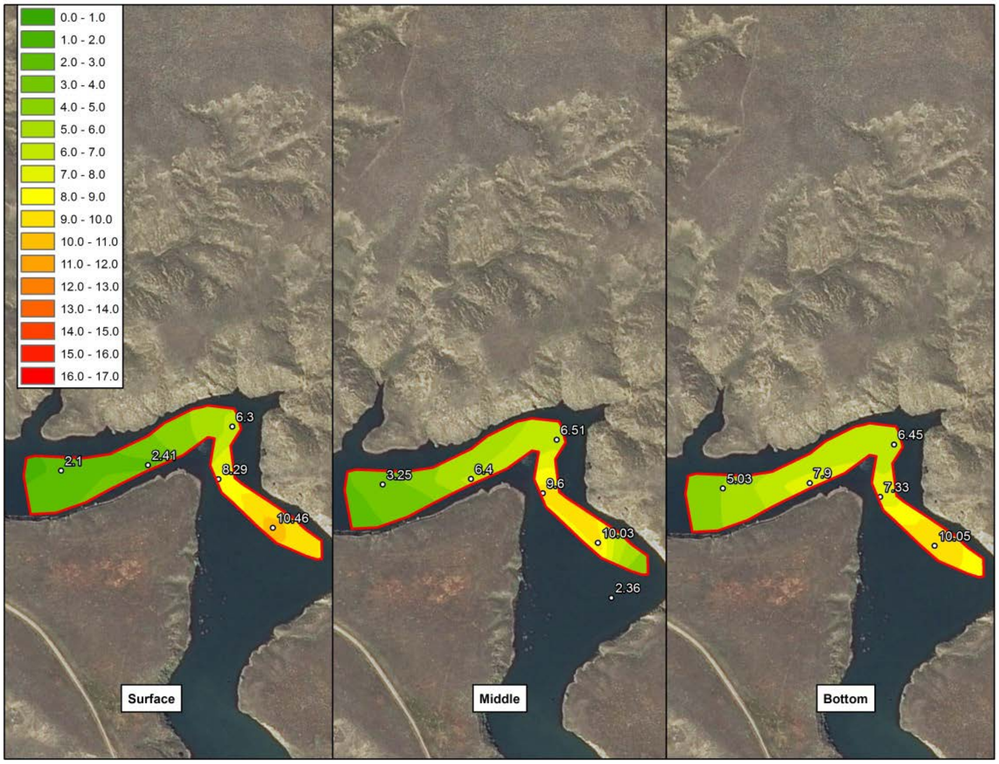


Figure 27. Mean endothall concentration (±SE) in Rock Creek North from 0 HAT to 1 DAT, Fort Peck Lake, MT, 2012.

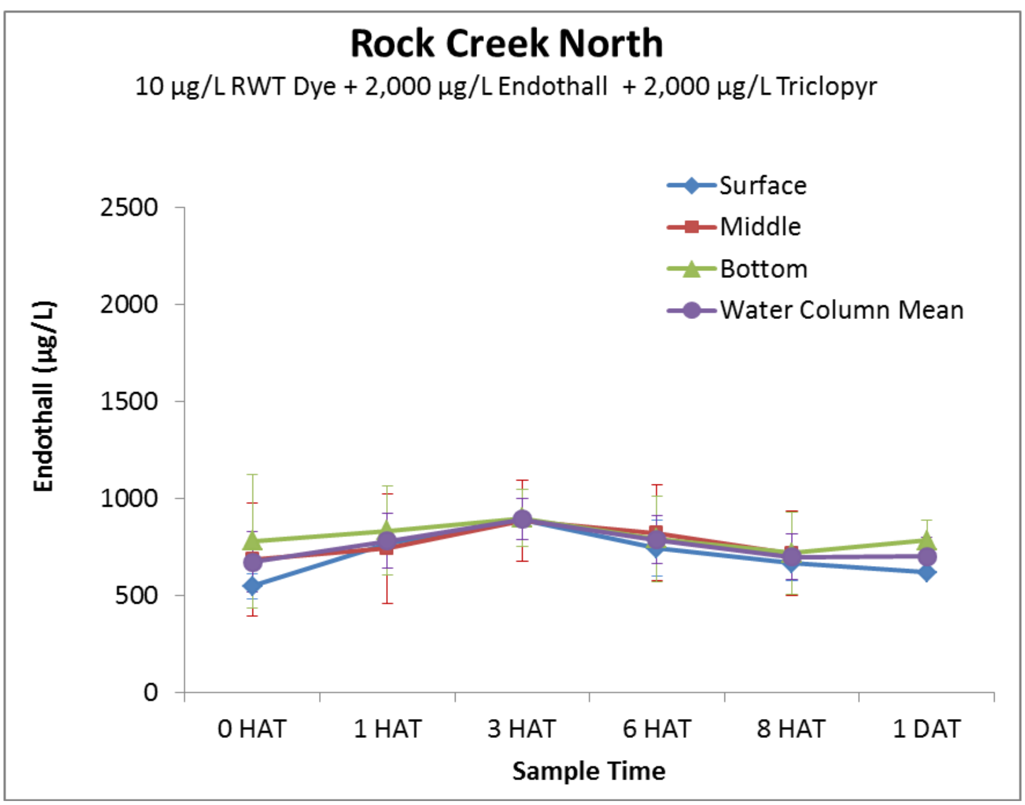
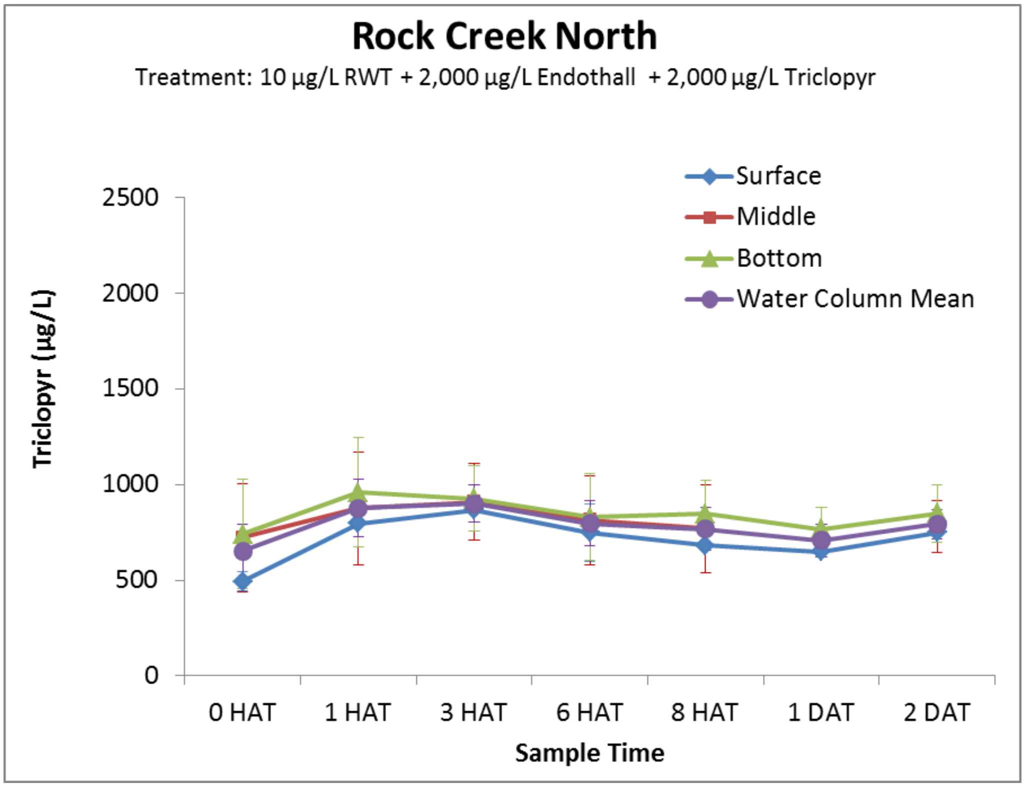


Figure 28. Mean triclopyr concentration (±SE) in Rock Creek North from 0 HAT to 1 DAT, Fort Peck Lake, MT, 2012.



Plant assessment and CET

The ranking of Eurasian watermifoil levels at pretreatment and post treatment sampling events are presented in Table 5. Concentrations of endothall, which were applied singularly in the Dredge Cut, were at or above 1,500 µg/L for at least 24 hr, which is estimated to provide between 70% and 85% control (Netherland et al. 1991a). Based on plant ranking assessments conducted 4 WAT, Eurasian watermilfoil decreased in the Dredge Cut from an average of 0.75 to 0.03, or 96%. However, by 50 WAT, the Eurasian watermilfoil growth had recovered with a 0.59 ranking, indicating control of only 22%. This amount of plant recovery was most likely due to herbicide-contact-time issues, suggesting that a greater CET period (2–3 days longer barrier deployment period) may be required to provide more effective, long-term control (1 yr or greater) of Eurasian watermilfoil in these settings.

Table 5. Mean ranking of common plant species pretreatment and 4 and 50 WAT.

	M. Spicatum (Eurasian watermilfoil)			*S. pectinata* (sago pondweed)		
Plot	Pre-	4 WAT	50 WAT	Pre-	4 WAT	50 WAT
Dredge Cut	0.75 ± 0.17	0.03 ± 0.03	0.59 ± 0.23	0.25 ± 0.08	0.00 ± 0.00	0.13 ± 0.06
Rock Creek South	3.88 ± 0.30	3.62 ± 0.27	0.04 ± 0.03	0.00 ± 0.00	0.02 ± 0.02	0.00 ± 0.00
Rock Creek North	1.9 ± 0.31	0.00 ± 0.00	0.00 ± 0.00	0.28 ± 0.13	0.00 ± 0.00	0.02 ± 0.00
Ref	4.24 ± 0.27	3.67 ± 0.41	0.16 ± 0.09	0.04 ± 0.04	0.08 ± 0.06	0.12 ± 0.07
	Chara spp (muskgrass)			*E. canadensis* (elodea)		
Plot	Pre-	4 WAT	50 WAT	Pre-	4 WAT	50 WAT
Dredge Cut	0.05 ± 0.03	0.22 ± 0.08	0.03 ± 0.03	0.05 ± 0.03	0.22 ± 0.08	0.09 ± 0.05
Rock Creek South	0.00 ± 0.00	0.12 ± 0.05	0.06 ± 0.03	0.00 ± 0.00	0.10 ± 0.04	0.00 ± 0.00
Rock Creek North	0.03 ± 0.03	0.02 ± 0.02	0.05 ± 0.01	0.4 ± 0.12	0.37 ± 0.08	0.00 ± 0.00
Ref	0.12 ± 0.09	0.29 ± 0.09	0.2 ± 0.08	0.04 ± 0.04	0.13 ± 0.07	0.08 ± 0.06
	V. americana (wildcelery)			*R. longirostris* (white water crowfoot)		
Plot	Pre-	4 WAT	50 WAT	Pre-	4 WAT	50 WAT
Dredge Cut	0.05 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.03	0.00 ± 0.00	0.00 ± 0.00
Rock Creek South	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Rock Creek North	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Ref	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	P. foliosus (leafy pondweed)			*Z. palustris* (horned pondweed)		
Plot	Pre-	4 WAT	50 WAT	Pre-	4 WAT	50 WAT
Dredge Cut	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Rock Creek South	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.02
Rock Creek North	0.00 ± 0.00	0.00 ± 0.00	0.07 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Ref	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.06	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Rock Creek South and North were treated with combinations of endothall and triclopyr. While efficacy results at 4 WAT were consistent with water-exchange-driven herbicide CET relationships, efficacy values measured at 50 WAT were complicated by the previously described prolonged lake-level drawdown in the 2012–2013 winter and the 2013 growing season. Therefore, 50 WAT vegetation assessment results in these plots must be viewed as a combination of herbicide treatment, followed by drawdown.

At Rock Creek South, strong winds from the northwest resulted in very low concentrations of endothall (below 300 µg/L throughout the study period), which is estimated to provide <70% control (Netherland et al. 1991a). Triclopyr concentrations were similarly low (less than 500 µg/L within 6 HAT) and estimated to provide <70% control (Netherland and Getsinger 1992). This pattern of low CET is further supported by water exchange measurements and aqueous herbicide residues (Figures 18-22). Epinastic leaves and stems, classic symptoms of triclopyr efficacy, were

not observed until 3 DAT. Further, plant assessments in Rock Creek South showed Eurasian watermilfoil only declined from 3.88 to 3.62 (7%) 4 WAT, most likely due to insufficient herbicide CET relationships. However, at 50 WAT, Eurasianwatermilfoil control was measured at 99%. While the herbicide treatment had little impact on Eurasian watermilfoil in the year of treatments, the prolonged lake-level drawdown (decrease of some 3 m) was most likely responsible for the lack of Eurasian watermilfoil at 50 WAT in this plot. Moreover, this plot was likely completely dry when minimum lake-level elevation occurred.

Conversely, in Rock Creek North, endothall averaged 700 µg/L at 1 DAT, suggesting that even in the absence of triclopyr, nearly 70% to 85% control might be expected (Netherland et al. 1991a). Triclopyr averaged 785 µg/L up to 1 DAT, suggesting that even in the absence of endothall, 70% to 85% control might be expected (Netherland and Getsinger 1992). Within 27 HAT, plants growing in Rock Creek North had epinastic leaves and stems. Results of plant assessments conducted 4 WAT found the average ranking of Eurasian watermilfoil in Rock Creek North decreased from 1.9 to 0.0 (100% control) (Table 5). This high level of control was maintained at 50 WAT but was arguably enhanced by the previously described lake-level drawdown.

Vegetation assessments showed that Eurasian watermilfoil measured in the untreated reference plot (also located in Rock Creek) shifted slightly from a ranking of 4.24 to 3.67 from pretreatment to 4 WAT, respectively. As shown in the herbicide treated plots in Rock Creek, the prolonged lake-level drawdown decreased Eurasianwatermilfoil ranking to 0.16 by 50.

Across all treatment plots, the diversity and ranking of native plants was quite low prior to treatment (Table 5). As previously mentioned, sago pondweed, muskgrass, and Canadian waterweed were the most common submersed plant species observed. In general, the mean ranking of sago pondweed declined while muskgrass and Canadian waterweed increased or did not appreciably change. Endothall is known to control sago pondweed and is used to control nuisance levels of that species in flowing water systems, such as irrigation canals (Slade et al. 2008). Native submersed aquatic plant species not found in the pretreatment or 4 WAT plant assessments included leafy pondweed (*Potamogeton foliosus*) and horned pondweed (*Zannichellia palustris*). These results are comparable to other field efforts using endothall alone and in combination with the

synthetic auxin 2,4-D (2,4-dichlorophenoxy acetic acid), with similar activity to the synthetic auxin triclopyr, to control Eurasian watermilfoil (Getsinger et al. 1997; Skogerboe and Getsinger 2006; Skogerboe et al., 2008; Skogerboe et al. 2o12; Getsinger et al. 2013a, 2013b) and suggests that Eurasian watermilfoil may be selectively controlled in Fort Peck Lake without compromising native vegetation.

4 Conclusions and Recommendations

Conclusions

Fort Peck Lake is a large and hydraulically complex reservoir. Extended fetches of open water, in association with strong prevailing winds, can compromise aquatic herbicide CET relationships in waters surrounding target plant stands. In addition, large and difficult-to-predict fluctuations in seasonal lake-level elevations can complicate annual aquatic plant management strategies, but they can aid in enhancing Eurasian watermilfoil control tactics. In general, the use of contact and quick-acting systemic herbicides can be successfully used to provide control of Eurasian watermilfoil in selected areas of Fort Peck Lake, if adequate herbicide CET relationships can be achieved. However, water-exchange patterns can reduce herbicide-contact-time requirements in treated areas and suppress the level of control in the year of treatment. This reduced efficacy can lead to regrowth of Eurasian watermilfoil the following growing season, resulting in short-term control. The following conclusions can be reached based on the research documented in this study:

- Understanding water-exchange relationships in areas targeted for submersed herbicide applications can be used to predict product efficacy.
- Eurasian watermilfoil can be adequately controlled in areas of the lake where water-exchange processes are reduced and required herbicide CET relationships can be maintained.
- The short-term use of a barrier curtain can greatly limit water exchange within treated plots and provide adequate endothall contact time, yielding acceptable Eurasian watermilfoil control.
- Relatively small treatment plots of <4 ha (10 acres) can be impacted by water-exchange processes in open fetch areas of the lake (primarily wind induced), thus decreasing herbicide contact time around target plants and greatly reducing efficacy.
- The variable-depth herbicide application method delivered herbicides to the bottom half of the water column and can be a useful method for delivering liquid herbicide formulations to plant stands that are growing in lower portions of the water column.
- Large and seasonal lake-level drawdowns can complicate aquatic herbicide applications, but if they can be predicted far enough in

advance, these dewatering events can be used to augment the efficacy of chemical treatments

Recommendations

Based on information documented in this study, the following recommendations are presented to fully determine and increase the efficacy of herbicides to control Eurasian watermilfoil in Fort Peck Lake:

- Evaluate efficacy at approximately 52 WAT after herbicide treatment to determine control of Eurasian watermilfoil beyond the season of application.
- Continue evaluations of barrier curtains to hydraulically separate sections of the lake to increase herbicide contact time around target plant stands. The use of barrier curtains can reduce bulk water exchange between the enclosed treatment site and surrounding untreated waters. This approach is recommended for bays with a high capacity for water exchange and will allow for the specified herbicide CET requirements against target plants.
- Barrier curtain–herbicide evaluations should be refined in areas of the system where wide fluctuations in water levels can be avoided (e.g., in the Dredge Cut area).
- Evaluate other contact (diquat, flumioxazin) and systemic (2,4-D, fluridone, penoxsulam) aquatic herbicides for use in Fort Peck Lake, including granular formulations of selected herbicides.
- Develop site-specific herbicide application strategies for controlling Eurasian watermilfoil as part of an overall plan to manage aquatic invasive plants on the lake and river.
- Evaluate the use of aquatic herbicide applications to control Eurasian watermilfoil along shoreline areas during dewatered conditions, particularly systemic compounds such as triclopyr and 2,4-D.
- Conduct bathymetric surveys in areas with known Eurasian watermilfoil populations. This information is needed to more accurately calculate the quantity of herbicide needed for submersed chemical applications.
- Continue monitoring populations of Eurasian watermilfoil on the lake to determine expansion of existing stands, new infestations, and potential infestations sites.
- Develop lake-level elevation maps to target survey efforts to areas inundated throughout the winter and thus most likely to support spring growth of Eurasian watermilfoil and other invasive aquatic

plants and to target areas that are likely to be dewatered during historical low water conditions to better predict when, and where, herbicide treatments will be most effective. This information will allow managers to prioritize survey and treatment areas in this large and hydraulically dynamic water body.

- Obtain aerial imagery using various color bands (red, green blue [RGB] and RGB + color infrared) to identify perennial and intermittent sources of water near the lake and river that could support year-round or year-season growth of Eurasian watermilfoil or other invasive aquatic plants.
- Increase boater awareness using *clean, dry, drain* messaging to prevent further spread of Eurasian watermilfoil and the invasive curlyleaf pondweed (*Potamogeton crispus*), as well as the introduction of other aquatic nuisance species (e.g., zebra or quagga mussels).

References

Boylen, C. W., L. W. Eichler, and J. D. Madsen. 1999. Loss of native aquatic plant species in a community dominated by Eurasian watermilfoil. *Hydrobiologia* 415:207–211.

Carpenter, S. R., and D. M. Lodge. 1986. Effect of submersed macrophytes on ecosystem processes. *Aquatic Botany* 26:341–370.

Fox, A. M., W. T. Haller, K. D. Getsinger, and D. G. Petty. 2002. Dissipation of triclopyr herbicide applied in Lake Minnetonka, MN concurrently with Rhodamine WT dye. *Pest Science Management* 58(7):677–86.

Frodge, J. D., G. L. Thomas, and G. B. Pauley. 1990. Effects of floating and submergent growth forms of aquatic macrophytes on littoral zone water quality. *Aquatic Botany* 38:231–248.

Getsinger, K. D., J. D. Madsen, M. D. Netherland, and E. G. Turner. 1996a. *Field evaluation of triclopyr (Garlon 3A) for controlling Eurasian watermilfoil in the Pend Oreille River, Washington*. Technical Report A-96-1. NTIS No. AD A304 807. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Getsinger, K. D., A. M. Fox, and W. T. Haller. 1996b. *Herbicide application technique development for flowing water: Summary of research accomplishments*. Miscellaneous Paper A-96-3. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Getsinger, K. D., and M. D. Netherland. 1997. *Herbicide concentration/exposure time requirements for controlling submersed aquatic plants: Summary of research accomplishments*. Miscellaneous Paper A-97-2. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Getsinger, K. D., E. G. Turner, J. D. Madsen, and M. D. Netherland. 1997. Restoring native plant vegetation in a Eurasian watermilfoil-dominated plant community using the herbicide triclopyr. *Regulated Rivers Research and Management* 13:357–375.

Getsinger, K. D., J. G. Skogerboe, J. D. Madsen, R. M. Wersal, J. J. Nawrocki, R. J. Richardson, and M. R. Sternberg. 2013a. *Selective control of Eurasian watermilfoil and Curlyleaf Pondweed in Noxon Rapids Reservoir, Montana: Aquatic herbicide evaluations 2009-2010*. Draft Technical Note. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Getsinger, K. D., J. G. Skogerboe, J. D. Madsen, R. M. Wersal, J. J. Nawrocki, R. J. Richardson, and M. R. Sternberg. 2013b. *Selective Control of Eurasian watermilfoil and Curlyleaf Pondweed in Noxon Rapids Reservoir, Montana: Herbicide strip-plot evaluations 2010-2011*. Draft Technical Note. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Madsen, J. 1999. *Point intercept and line intercept methods for aquatic plant management*. Aquatic Plant Control Technical Note MI-02. February 1999.

Madsen, J. 2009. Chapter 13.2: Eurasian watermilfoil. In *Biology and Control of Aquatic Plants: A Best Management Practices Handbook*, ed. L. A. Gettys, W. T. Haller, and M. Bellaud, 95–98. Marietta, GA: Aquatic Ecosystem Restoration Foundation.

Montana Department of Agriculture (MDA). 2010. *Montana noxious weed list*. http://agr.mt.gov/agr/Programs/Weeds/PDF/weedList2010.pdf

Netherland, M. D., W. R. Green, and K. D. Getsinger. 1991a. Endothall concentration and exposure time relationships for the control of Eurasian watermilfoil and hydrilla. *Journal of Aquatic Plant Management* 29:61–67.

Netherland, M. D., W. R. Green, and K. D. Getsinger. 1991b. *Endothall concentration and exposure time relationships for the control of Eurasian watermilfoil and hydrilla*. Miscellaneous Paper A-91-A. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Netherland, M. D., and K. D. Getsinger. 1992. Efficacy of triclopyr on Eurasian watermilfoil: concentration and exposure time effects. *Journal of Aquatic Plant Management* 30:1–5.

Netherland, M. D., K. D. Getsinger, and E. G. Turner. 1993. Fluridone concentration and exposure time requirements for control of Eurasian watermilfoil and hydrilla. *Journal of Aquatic Plant Management* 31:189–194.

Netherland, M. D., D. R. Honnell, A. G. Staddon and K. D. Getsinger. 2002. Comparison of immunoassay and HPLC for analyzing fluridone concentrations: New applications for immunoassay techniques. *Lake and Reservoir Management* 18(1):75–80.

Prentki, R. T., M. S. Adams, S. R. Carpenter, A. Gasith, C. S. Smith, and P. R. Weiler. 1979. The role of submersed weedbeds in internal loading and interception of allochthonous materials in Lake Wingra, Wisconsin, USA. *Archives of Biology, Supplement* 57:221–250.

Skogerboe, J. G., and Getsinger, K.D. 2006. *Selective control of Eurasian watermilfoil and curlyleaf pondweed using low doses of endothall combined with 2,4-D*. ERDC/TN APCRP-CC-05. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Skogerboe, J. G., K. D. Getsinger, and A. G. Poovey. 2012. *Early season applications of endothall and 2,4-D for the selective control of Eurasian watermilfoil and curlyleaf pondweed in Minnesota lakes: Year two of submersed plant communities*. ERDC/TN APCRP-CC-13. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Skogerboe, J. G., A. G. Poovey, K. D. Getsinger, W. Crowell, and E. Macbeth. 2008. *Early-season, low-dose applications of endothall to selectively control curlyleaf pond weed in Minnesota lakes*. ERDC/TN APCRP-CC-08. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Slade, J. G., A. G. Poovey, and K. D. Getsinger. 2008. Concentration/exposure time relationships for controlling sago pondweed (*Stuckenia pectinata*) with endothall. *Weed Technology* 22:146–150.

Turner, E. G., K. D. Getsinger, and M. D. Netherland. 1994. Correlation of triclopyr and rhodamine WT dye dissipation in the Pend Oreille River. *Journal of Aquatic Plant Management* 32:39–41.

U.S. Army Corps of Engineers (USACE). 2006. *Missouri River mainstem system master water control manual: Missouri River Basin*. Omaha, NE: Reservoir Control Center, U.S. Army Corps of Engineers, Northwest Division–Missouri River Basin.

_____. 2011. *2010 Report: Water quality conditions in the Missouri River system*. Prepared by the Water Quality Unit, Water Control and Water Quality Section, Hydrologic Engineering Branch, Engineering Division, Omaha District.

U.S. Fish and Wildlife Service (USFWS). 2003. *Amendment to the 2000 biological opinion on the Missouri River main stem reservoir system, operations and maintenance of the Missouri River bank stabilization and navigation project, and operation of the Kansas River system Dec 16, 2003*. U.S. Department of the Interior, Fish and Wildlife Service.

_____. 2012. Final comprehensive conservation plan and environmental impact statement: Charles M. Russell National Wildlife Refuge, UL Bend National Wildlife Refuge. Volume 1. Lakewood, Colorado. U.S. Department of the Interior, Fish and Wildlife Service, Mountain-Prairie Region.

Wersal, R. M., and J. D. Madsen. 2011. *Evaluating plant response to triclopyr applied alone and in combination with endothall in Noxon Rapids Reservoir for 2010: Phase 2*. Geosystems Research Institute Report 5046. Starkville, MS: Mississippi State University.

Appendix A: Regulation Zone, Pool Elevation, Surface Area, Volume, Mean Depth, and Retention of Fort Peck Lake

Pool Elevation (Feet MSL)	Regulation Zone	Surface Area (Acres)	Volume (Acre-feet)	Mean Depth (Feet)	Retention Time (Years)
2,250 to 2,246	Exclusive Flood Control Zone	245,405 to 237,605	18,462,840 to 17,253,500	75.2 to 72.6	2.81 to 2.62
2,246 to 2,234	Annual Flood Control and Multiple Use Zone	237,605 to 213,025	17,253,500 to 15,000,180	72.6 to 70.4	2.62 to 2.28
2,234 to 2,160	Carryover Multiple Use Zone	213,025 to 89,461	15,000,180 to 4,087,903	70.4 to 45.7	2.28 to 0.62
2,160 to 2,030	Permanent Pool Zone	<89,461	<4,087,903	<45.7	<0.62

Appendix B: Stakeholder Outreach

Several town hall meetings were conducted as stakeholder outreach efforts to review and discuss the proposed herbicide evaluations. One was held at the Montana Invasive Species Summit (17 Jan 2012), and two were held at the Fort Peck Lake Interpretive Center (10 May and 7 Aug 2012). These meetings were hosted by the Fort Peck Project Office by Patricia Gilbert. Additionally, Gilbert presented the proposed work to the Montana Noxious Weed Control Association.

Stakeholders were informed that the herbicides proposed for the evaluation are aquatic formulations of endothall and triclopyr. These products are approved by the USEPA and the Montana Department of Agriculture and were evaluated in *Environmental Assessment and Findings of No Significant Impact: Control of Eurasian Watermilfoil, Fork Peck Project Area, Various Counties, MT*.

No major objections to conducting the trials were expressed during the meetings. However, Montana Fish, Wildlife, and Parks personnel expressed some concern about indirect effects of the herbicides on DO levels, following treatment and subsequent plant death in the treated areas. This concern was addressed by measuring DO levels in the water column of the plots at pre- and post-treatment.

Appendix C: Product Label Use Restrictions

Endothall: It is a violation of Federal law to use aquatic herbicides in a manner inconsistent with its USEPA-approved labeling. Quiescent or slow moving waters treated with Aquathol K have no restrictions for swimming, fishing, or irrigation.[1] Waters treated with Aquathol K should not be used for animal consumption for up to 25 days, depending on the application rate.[2] The drinking water setback from *functioning* potable water intakes in the treated water body must be greater than or equal to 600 ft. The concentration of endothall acid in drinking (potable) water should not exceed the maximum contamination level (MCL) of 0.1 parts per million (ppm). There were no potable water intakes within 600 ft of any plots treated with endothall.

Triclopyr: For waters treated with triclopyr (Kraken), there are no restrictions on swimming, fishing, livestock consumption, or grazing (except lactating dairy animals). The setback for potable water intake structures during applications of triclopyr is determined by the treatment area (acres) and the concentration of triclopyr. Based on the concentration of triclopyr used for this project, presented in the following table, the potable water setback was 1,600 ft; however, there were no functioning potable water intakes within 1,600 ft of any plots treated with triclopyr.

[1] Treated water can be used for irrigating turf, ornamental plants, and crops immediately after treatment with the following exceptions: Do not use treated water to irrigate the following for 7 days after the treatment: annual nursery or greenhouse crops including hydroponics and newly seeded or transplanted annual crops, newly seeded or transplanted ornamentals, and newly sodded or seeded turf.

[2] Animal consumption restrictions based on application rate where, 0.5 ppm dipotassium salt –7 days; 4.25 ppm–14 days; and 5.0 ppm–25 days.

Minimum setback distances for the application of Kraken from functioning potable water intakes.

	Concentration of Triclopyr Acid in Water (ppm ae)				
	0.75	1.0	1.5	2.0	2.5
Area Treated (acres)	Required Setback Distance (feet) from Potable Water Intake				
<4	300	400	600	800	1,000
>4 - 8	420	560	840	1,120	1,400
>8 - 16	600	800	1,200	1,600	2,000
>16 - 32	780	1,040	1,560	2,080	2,600
>32 aces, calculate a setback using the formula for the appropriate rate at right	Setback (ft) = (800*ln (acres) – 160)/3.33	Setback (ft) = (800*ln (acres) – 160)/2.5	Setback (ft) = (800*ln (acres) – 160)/1.67	Setback (ft) = (800*ln (acres) – 160)/1.25	Setback (ft) = (800*ln (acres) – 160)

Appendix D: Rhodamine WT Fluorescent Dye for Use in Determining Bulk Water Exchange Processes, as Related to Aquatic Herbicide Applications

The inert tracer fluorescent dye, rhodamine WT (RWT), will be utilized for the aquatic herbicide study on Fort Peck Lake, MT. The RWT will be applied in conjunction with the herbicides (endothall and triclopyr) used to control Eurasian watermilfoil. The RWT dye is not an adjuvant, and since in-water, submersed treatments will be conducted, no adjuvants will be used in the study. While adjuvants (e.g., stickers/spreaders) are routinely used for emergent plant and/or terrestrial applications, they are sparingly used to treat submersed plants.

Rhodamine WT dye has been used to measure water exchange and flows in the United States for over 40 yr. This research group pioneered the use of RWT to mimic aquatic herbicide dispersion in the late 1980s, and the dye has been used since that time, including many water-exchange studies in USACE reservoirs (see References at end of appendices). Many of these studies have been in cooperation and/or consultation with the USEPA, the U.S. Fish and Wildlife Service, Tennessee Valley Authority, and other Federal agencies.

This dye has been approved by the USEPA for use over potable water intakes at an aqueous concentration of 0.01 mg/L (10µg/L). For the water exchange studies, 0.01 mg/L (10µg/L) or less are targeted. As shown on the Material Safety Data Sheet (MSDS), the reported LC 50 levels for RWT versus rainbow trout are 330 mg/L (320,000 µg/L) and for daphnia are 170 mg/L (170,000 µg/L), well above the nominal concentration of 0.01 mg/L.

In order to detect the very low levels of RWT applied in the studies, an instrument called a fluorometer is used, which can measure dye as low as 0.1µg/L (0.0001 mg/L). Aqueous dye concentrations of 10µg/L are essentially undetectable to the human eye, so measurements with a fluorometer are required. The dye usually degrades in the water column within a few days.

A number of fluorescent dyes are commercially available, but relatively few are suitable for water tracer studies (Wilson et al. 1986). Dyes that have been used in tracer studies include fluorescein, lissamine FF, rhodamine B, and RWT. The properties of RWT are well-suited to most studies and this is the dye most commonly used as a water tracer (Martin and McCutcheon 1999). Wilson et al. (1986) outlined the following desirable properties of RWT for tracer studies:

- high solubility in water
- high fluorescence – easily detectable
- fluorescent in a part of the visible spectrum not common to materials generally found in water, thereby reducing the problem of background fluorescence
- harmless in low concentrations
- inexpensive
- reasonably stable in a normal water environment.

Health and safety are primary considerations in the aquatic application of tracer dyes, including potential toxic effects on lake biota and effects on human health. Concentrations of dye known to affect biota are generally much higher than those required for tracer studies (Martin and McCutcheon 1999). In the presence of high nitrite concentrations (more than 1 mg/L) RWT has been found to form the carcinogen diethylnitrosamine (DENA). The potential for DENA formation is very low in surface water bodies because of relatively low nitrite concentrations in these waters. The USEPA and the U.S. Geological Survey have adopted a policy that prohibits the injection of fluorescent dyes in quantities that would result in dye concentrations greater than 10 μg/L at drinking water intakes.

Hazardous Materials Identification System ratings are presented in the MSDS for health (moderate hazard), flammability (slight hazard), and reactivity (slight hazard) for RWT. According the to Environmental and Water Quality Operational Studies by the USACE, "Rhodamine WT has been chosen as the dye most suitable for use in inflow studies" and "poses no known environmental or health hazards when used in unpolluted waters." Therefore, RWT has been selected for use in the study based on the characteristics noted and experience using this dye in many similar tracer studies.

The RWT formulation was developed specifically for water tracing and can be monitored and quantified in-situ using a portable fluorometer (or analyzer with an appropriate sensor). Several studies have shown significant correlations between dissipation patterns of this dye and those of aquatic herbicides fluridone, endothall, and triclopyr (Fox, Haller and Shilling 1991; Fox, Haller and Getsinger 1992, 1993; Getsinger et al. 1996). Results from these studies indicated that aquatic herbicide dissipation can be predicted by monitoring dye movement and concentration. Correlations in dispersal patterns must first be established for any given herbicide.

The regulatory standards that apply to the use of RWT are as follows:

- The standards established by the USEPA in the Federal Register (Vol. 63, No. 40) state the maximum RWT concentrations to be 10 µg/L for water entering a drinking water plant (prior to treatment and distribution) and 0.1µg/L in finished drinking water.
- The drinking water standard established by the National Sanitation Foundation (NSF) in the NSF Standard 60 state the maximum concentration of RWT to be 0.1 mg/L (100 µg/L).

The chemical formula of RWT dye is $C_{29}H_{29}ClN_2Na_2O_5$. The elemental composition is presented in the following Table. This compound is reportedly chemically inert and characterized by the presence of the xanthene nucleus ($C_{13}H_{10}O$).

Rhodamine WT has the most numerous qualities preferred by many state and federal agencies for open-channel studies. Also, fluorescent dye tracers do not usually require formal permits for use in a study (ASTM D5613 - 94(2008) Standard Test Method for Open-Channel Measurement of Time of Travel Using Dye Tracers).

Elemental composition of RWT				
Element	Symbol	Atomic Mass	# of Atoms	Mass %
Carbon	C	12.0107	29	61.43%
Hydrogen	H	1.0079	29	5.16%
Chlorine	Cl	35.4532	1	6.25%
Nitrogen	N	14.0067	2	4.94%
Sodium	Na	22.9897	2	8.11%
Oxygen	O	15.9994	5	14.11%

References

Fox, A. M., W. T. Haller, and D. G. Shilling. 1991. Correlation of fluoridone and dye concentrations in water following concurrent application. *Pesticide Science* 31:25–36.

Fox, A. M., W. T. Haller, and K. D. Getsinger. 1991. Factors that influence water exchange in spring-fed tidal canals. *Estuaries* 14(4):404–413.

Fox, A. M., W. T. Haller, and K. D. Getsinger. 1992. Correlation of bensulfuron methyl and dye concentrations in water following concurrent application. *Journal of Aquatic Plant Management* 30:73–74.

Fox, A. M., W. T. Haller, and K. D. Getsinger. 1993. Correlation of endothall and fluorescent dye concentrations following concurrent applications in tidal canals. *Pesticide Science* 37:99–106.

Fox, A. M., W. T. Haller, K. D. Getsinger, and W. R. Green. 1991. *Characterization of water movement in hydrilla-infested, tidal canals of the Crystal River, Florida*. MP A 91-2. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Fox, A. M., W. T. Haller, K. D. Getsinger, and D. G. Petty. 2002. Dissipation of triclopyr herbicide applied in Lake Minnetonka, MN, concurrently with rhodamine WT dye. *Pest Management Science* 58:677–686.

Getsinger, K. D., A. M. Fox, and W. T. Haller. 1996. *Herbicide application technique development for flowing water: Summary of research accomplishments*. MP A-96-3. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Getsinger, K. D., J. D. Madsen, T. J. Koschnick, and M. D. Netherland. 2002. Whole lake fluridone treatments for selective control of Eurasian watermilfoil: I. Application strategy and herbicide residues. *Journal of Lake and Reservoir Management* 18(3):181–190.

Getsinger, K. D., D. G. Petty, J. D. Madsen, J. G. Skogerboe, B. A. Houtman, W. T. Haller, and A. M. Fox. 2000. Aquatic dissipation of the herbicide triclopyr in Lake Minnetonka, Minnesota. *Pest Management Science* 56:388–400.

Getsinger, K. D., J. D. Madsen, R. M. Wersal, J. G. Skogerboe, J. J. Nawrocki, R. J. Richardson, and M. R. Sternberg. 2013. *Selective control of Eurasian watermilfoil and curlyleaf pondweed in Noxon Rapids Reservoir,Montana: Herbicide strip-plot evaluations 2010-2011*. Draft Technical Report. Vicksburg, MS: U.S. Army Engineer Research and Development Center, Environmental Laboratory.

Getsinger, K. D., J. G. Skogerboe, J. D. Madsen, R. M. Wersal, J. J. Nawrocki, R. J. Richardson, and M. R. Sternberg. 2013. *Selective control of Eurasian watermilfoil and curlyleaf pondweed in Noxon Rapids Reservoir, Montana: Aquatic herbicide evaluations 2009-2010*. ERDC/EL TR-13-5. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Getsinger, K. D., E. G. Turner, J. D. Madsen, and M. D. Netherland. 1996. *Field evaluation of triclopyr (Garlon 3A) for controlling Eurasian watermilfoil in the Pend Oreille River, Washington*. Technical Report A-96-1. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Getsinger, K. D., S. L. Sprecher, K. A. Langeland, W. T. Haller, A. M. Fox, and J. C. Joyce. 1994. *Dissipation of the herbicide bensulfuron methyl in Lake Seminole, Georgia*. TR A-94-4. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Getsinger, K. D., E. G. Turner, J. D. Madsen, and M. D. Netherland. 1997. Restoring native plant vegetation in a Eurasian watermilfoil-dominated plant community using the herbicide triclopyr. *Regulated Rivers Research and Management* 13:357–375.

Martin, J. L., and S. C. McCutcheon. 1999. *Hydrodynamics and transport for water quality modeling*. Boca Raton, FL: CRC Press.

Poovey, A. G., K. D. Getsinger, J. G. Skogerboe, T. J. Koschnick, J. D. Madsen, and R. M. Stewart. 2004. Small-plot, low-dose treatments of triclopyr for selective control of Eurasian watermilfoil. *Journal of Lake and Reservoir Management* 20 (4):322–332.

Turner, E. G., K. D. Getsinger, and E. R. Burns. 1995. *Chemical control field studies and demonstrations on Guntersville Reservoir*. Joint Agency Project Guntersville Project Aquatic Plant Management Report, Tennessee Valley Authority, Muscle Shoals, AL, and U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Turner, E. G., K. D. Getsinger, and M. D. Netherland. 1994. Correlation of triclopyr and rhodamine WT dye in the Pend Oreille River. *Journal of Aquatic Plant Management* 32:39–41.

Turner, E. G., M. D. Netherland, and K. D. Getsinger. 1991. Submersed plants and algae as factors in the loss of Rhodamine WT dye. *Journal of Aquatic Plant Management* 29:113–115.

Wilson, J. F., E. D. Cobb, and F. A. Kilpatrick. 1986. Fluorometric procedures for dye tracing, techniques of water-resources investigations of the United States Geological Survey. Applications of Hydraulics, Book 3, Chapter A12. Washington, DC: U.S. Geological Survey.

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14. ABSTRACT
In 2012, field trials were conducted in Fort Peck Lake to evaluate herbicides for controlling Eurasian watermilfoil and to provide management guidance. Plots of 1 to 3 hectares were treated with the herbicides (Dredge Cut, endothall at 2000 micrograms per liter (µg/L); Rock Creek South, endothall at 2500 µg /L, triclopyr at 2000 µg /L; Rock Creek North, endothall at 2000 µg/L, triclopyr at 2000 µg /L; Reference, no herbicides) using a variable-depth application technique. The Dredge Cut was an open-water site protected with a barrier curtain to sequester water exchange, where endothall wase maintained ~ 1500 µg/L for 24 hours after treatment (HAT), providing 96% control of milfoil by 4 WAT but only 22% control at 50 WAT. Rock Creek South was an open-water plot where water exchange processes diluted herbicide levels (endothall < 300 µg /L and triclopyr < 500 µg /L by 6 HAT), and milfoil control was limited to 7% at 4 WAT and 99% control at 50 WAT. Limited water exchange processes in Rock Creek North resulted in slow dissipation of herbicides (endothall ~ 700 µg /L and triclopyr ~ 800 µg /L for 24 HAT), and milfoil control was 100% at 4 and 50 WAT. Periods of low water levels in the lake impacted the 50 WAT efficacy results in plots above the dam. Native vegetation was sparse in all plots but survived treatments with an increase in species diversity at 50 WAT. Treatments had no impacts on water quality including dissolved oxygen levels. Adequate control of milfoil can be achieved in areas of the lake where water exchange processes are reduced and herbicide concentrations surrounding target plant stands can be maintained.

15. SUBJECT TERMS (see reverse)

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